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SCIENCE AND LIFE IN THE WORLD

A Challenge to the World

VOLUME III

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THE GEORGE WESTINGHOUSE CENTENNIAL FORUM

SCIENCE AND LIFE IN THE WORLD

VOLUME I

Science and Civilization
The Future of Atomic Energy

VOLUME II

Transportation—
A Measurement of Civilization
Light, Life, and Man

VOLUME III

A Challenge to the World

SCIENCE AND LIFE IN THE WORLD

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THE
GEORGE WESTINGHOUSE
CENTENNIAL FORUM
May 16, 17, *and* 18, 1946

Sponsored by
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VOLUME III

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SCIENCE AND LIFE IN THE WORLD

A Challenge to the World

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SECOND PRINTING

Dedicated to

THE INVENTORS AND PIONEERING
INDUSTRIAL ORGANIZERS OF THE WORLD,
AS EXEMPLIFIED BY THE LIFE
AND WORK OF GEORGE WESTINGHOUSE

THE GEORGE WESTINGHOUSE CENTENNIAL FORUM

The George Westinghouse Centennial Forum, held in Pittsburgh on May 16, 17, and 18, 1946, to commemorate the one hundredth anniversary of the birth of George Westinghouse—one of America's most renowned inventors and industrialists—constituted a most significant gathering of distinguished scientists, scholars, and leaders in the world of industry. Twenty-four leaders in the field of science and technology were invited to participate in a remarkable symposium that summarized all of our current knowledge and pointed the way toward future research and development. Many of the speakers were intimately connected with the tremendous research and development in all fields of science brought about by the Second World War. The summary of the new knowledge thus gained, together with its implications for the present and future generations, is the theme of all of these significant papers. In these volumes are offered, to all specialists in the fields of science and sociology as well as to the general reader, a verbatim transcript of each of these addresses. In them will be found a thorough analysis of the perplexing problems of our day.

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A Challenge to the World

Marvin W. Smith, *Chairman*, Westinghouse Educational Foundation. During 31 years of service with Westinghouse, this descendant of one of Texas' most distinguished soldiers has carried on century-old tradition of pioneering by directing new engineering developments in electrical world. As vice-president in charge of all engineering activities, has been instrumental in creating many huge generating units for power projects—Conowingo (on Susquehanna River), Boulder Dam, Norris Dam, and others. Promoted the umbrella-type construction for water-wheel generators, design almost universally used in low-speed hydraulic power stations. Has several inventions to his credit, has delivered many papers before scientific and professional societies. In 1938 received Order of Merit from Westinghouse for "capable and aggressive leadership."

Commentary

MARVIN W. SMITH

Chairman, Westinghouse Educational Foundation
Vice-president, Westinghouse Electric Corporation

We who live here in Pittsburgh have long since learned to appreciate its importance as a scientific and industrial center. It has earned this position of prestige through its institutions of learning, such as the Carnegie Institute of Technology, Duquesne University, and the University of Pittsburgh, and also through its great industrial research laboratories such as Mellon Institute and many others maintained by the coal, oil, aluminum, steel, and electrical manufacturing industries in this district.

As chairman of the Westinghouse Educational Foundation, "I am certainly glad to have this opportunity to welcome you here to Pittsburgh so that you may learn more about its scientific interests and activities, and I especially want to express our appreciation and delight in having all of you join with us through your support and participation in this Forum. We feel sure that it will not only add further to Pittsburgh's scientific stature but will contribute materially to the general fund of scientific knowledge for the benefit of "Science and Life in the World."

Science and Civilization

BY

GWILYM A. PRICE

President, Westinghouse Electric Corporation

Gwilym A. Price, *President*, Westinghouse Electric Corporation. As the chief executive officer of Westinghouse, is one of America's youngest heads of a major corporation. Former president of Peoples-Pittsburgh Trust Company, was elected vice-president of Westinghouse in 1943, becoming executive vice-president and a member of the board in 1945. His career as an attorney interrupted by First World War, he left a law firm to become assistant trust officer of the Pittsburgh Trust Company in 1920, trust officer of Peoples-Pittsburgh, 1923; vice-president, 1930; president, 1940. Director of Blaw-Knox Company, South Penn Oil Company, National Union Fire Insurance Company, and Peoples-Pittsburgh Trust Company. Trustee of Central Hanover Bank and Trust Company, Pennsylvania College for Women, Allegheny College, and Magee Hospital.

Science and Civilization

TODAY, MORE THAN EVER BEFORE IN HISTORY, WE must be aware of the far-reaching effects that scientific advances are impressing upon our society and our institutions. That so many of you—business and professional men, educators and civic leaders—have taken time from your busy days to attend this meeting, where many of the world's foremost scientists will add their thoughts to our thinking, is a wonderful sign of singleness of purpose and determination to build a well-reasoned and sound future from the devastations of war.

The Westinghouse Educational Foundation, which is sponsoring this Forum, is an organization endowed by the Westinghouse Electric Corporation for the purpose of promoting science and education. One of its most widely known activities is the Science Talent Search, which for the past four years has focused the spotlight on high-school seniors gifted with a talent in science and has given these young men and women substantial support in the continuation of their scientific and technical training.

The Educational Foundation offers other undergraduate scholarships as well and maintains collegiate fellowships and professorships. Recently it established annual Science Writers Awards to encourage the dissemination of scientific information, and some of the first winners of these awards are with us today.

In sponsoring this scientific Forum in commemoration of the one-hundredth anniversary of the birth of George Westinghouse, the Board of Trustees of the Foundation believes that such a meeting epitomizes in the very broadest sense the objective of the Foundation—to promote science and education.

There is a happy propriety of time and place in this gathering. We Pittsburghers are proud of the place this city takes as one of the leading centers of research in the pure and applied natural sciences. In this city is located Mellon Institute, at which 500 scientists, engineers, and technicians are at work on some eighty comprehensive investigational programs for public and professional benefit.

Here, too, are the Gulf Research Laboratories, the metallurgical laboratories of the world's leading steel producers, bituminous coal research laboratories, the concentrated laboratory talent of Carnegie Institute of Technology, the medical and engineering laboratories of the University of Pittsburgh, the laboratories of the Aluminum Company of America and the Pittsburgh Plate Glass Company, the food laboratories of the H. J. Heinz Company, and last—and we hope not least—the Westinghouse Research Laboratories.

In all, the Pittsburgh area has scientific and industrial research centers employing 1,300 scientists and engineers, and expending about $7,800,000 a year on scientific and engineering research. For a group interested in exploring the new horizons of science, this is indeed a propitious place to meet.

There is a propriety, too, in the time of this meeting, coming as it does so shortly after the termination of global war. Nobody can escape the meaning of the scien-

tific frontiers that have been opened to us during the past five or ten years. Instruments, techniques, theories—all developed for purposes of destruction—have given us a new wealth and a new challenge. The awesome power that we now have for destruction has given us a new, and I hope a lasting, realization of the impact of science on our affairs. In return for our new-found wealth we are forced to assume new and critical responsibilities. We must view the bewildering number of forces and agencies we now have and, with conviction and faith, shape them to good purposes.

It is fitting, too, that this event should be in commemoration of the one-hundredth anniversary of the birth of George Westinghouse. Westinghouse was born in the midst of a scientific and industrial awakening. One hundred years ago, the railroad had definitely arrived and was pushing slowly inland from the Atlantic coast. Steamboats were making their appearance on inland rivers and lakes. The first screw-propelled vessel of war, marking a new epoch in marine engineering, made its appearance in 1844, two years before George Westinghouse was born. In that same year, 1844, the first National Science Congress met in Washington, D.C., attended by 300 leading scientists of the country; and in the same year the Smithsonian Institution was established.

Cradled in these years of scientific awakening, George Westinghouse reached maturity at a time when these new developments could have—and did have—a profound effect on industrial advancement, and his career expressed the creative attitude that we hope this Forum will help engender in this day and age.

George Westinghouse was more than an industrialist who founded sixty different companies all over the world.

He was more than an inventor who received 361 patents over a period of less than half a century. He was a creative leader and visionary in one of the most creative historical periods of industrial growth.

Early in his career, when railroads were becoming the lifeline of the nation, he invented the air brake, one of the greatest contributions to safety in transportation. Later he pioneered in the development of railway signals and interlocking switches; he invented a safe and efficient mechanism for joining railway cars; he brought out the first main-line electric locomotive and was a pacemaker in modern railway electrification.

When the nation's industries needed power, he developed a system for transmitting and using natural gas and topped this with perhaps his greatest contribution of all—today's alternating-current system of generating, transmitting, and utilizing electricity for power and light.

To modern world commerce he gave a perfected steam turbine, geared to drive ships, and with this paved the way for the development of powerful present-day fleets.

Today, one hundred years after his birth, scarcely a man lives in America whose life and activity have not been affected by what George Westinghouse did. For he had the power to read in the circumstances about him the fundamental needs for the future. He had the stamina and inventive genius to view these needs as his challenge, and he had the determination to follow a course of action that he knew would bring widespread benefits.

Precisely these characteristics are needed today, whether we are scientists or not. We are faced with a confusing array of new forces, not the least of which are the scientific advances we have heard about and will hear more about during this Forum. These are the circum-

stances with which we must deal, and we must read into them the needs of the future and act accordingly.

One fact we must not forget, one problem stands like a colossus before us—that the destructive forces which have come from this war make our obligation to prevent another war immediate and inescapable. Nobody can exaggerate the overwhelming power of these destructive forces. If we ever allow ourselves, by thought, or action, or faltering courage, to permit these forces to be unleashed, we will have committed the most tragic crime in all history. The great cities, the great enterprises, the great institutions that we represent will be as dust.

Prior to the war, our ideals were little more than habit. Challenged as they were by conflicting ideals, they are now convictions. We must not for one moment lose sight of these convictions. The need to act on them now is urgent.

It is our sincere hope that this Forum will help in some way to focus the world's attention on the wealth of scientific discoveries and technological tools at our command. It is our hope that an understanding of the importance of these developments will enable us to see more clearly the rich future that lies before us, if we can somehow get to understand and trust one another as individuals and as nations. If the Forum succeeds in helping to achieve these ends, it will have more than served its purpose, and it is with this hope that I extend to you our greetings today.

Partners in Science

BY

DR. L. W. CHUBB

Director, Westinghouse Research Laboratories

Dr. L. W. Chubb, *Director*, Research Laboratories, Westinghouse Electric Corporation. Eminent inventor and authority in every field of electricity, has served Westinghouse for over 40 years. By research and development, contributed importantly to America's military proficiency during both world wars. Delegate to International Electrotechnical Commission in London and Brussels, 1919–1920. When Westinghouse staged pioneer commercial broadcast at KDKA in 1920, took charge of Radio Engineering Department, helping in succeeding years to guide radio from crystal-set era into age of mass production. Awarded Order of Merit by Westinghouse and Lamme Medal by Ohio State University. A prolific inventor, he has been granted in his own name more than 200 patents, distributed through a number of technical fields. Awarded John Fritz Medal, 1946.

Partners in Science

THIS WESTINGHOUSE ANNIVERSARY, WHICH BRINGS together such eminent authorities in pure science, research, education, government, engineering, and industry, makes timely a discussion on how the activities of those in these various fields of endeavor affect one another.

We are all strongly aware that our present-day, highly complex, material civilization was predominantly derived from fundamental research and engineering in the past, and that future growth depends upon present and future research and technological application.

In the past, development in the "machine age" depended upon the application of scientific knowledge collected for years by scientists and applied by a few geniuses such as George Westinghouse. Today, this slow method of technological development will no longer suffice. Watt and his teakettle are replaced by men highly trained in thermodynamics and superacoustic gas flow. Goodyear and his kitchen stove are succeeded by men with knowledge of statistical mechanics of long-chain polymers, working in laboratories equipped with the most precise instruments and the best of facilities. Scientific knowledge is urgently needed in ever-increasing quantities, and its application in industry must be more promptly attained to meet the demands of our modern civilization.

The more rapid unfolding of the secrets of nature, the encouragement given to scientific pursuits, and, especially,

the technical accomplishments during the late war, have all shown more than ever before the great influence of science on the national welfare. This influence may be for good or for evil, depending upon our sufficiency of wisdom to control our affairs.

Assuming that controls will be found to protect against the potential dangers of the misuse of science, we must continue to accelerate our scientific activities to improve further the living conditions and the ability of the public to satisfy its wants.

Suitable incentives, effective stimulation, and successful educational methods must be found to locate and develop the various talented workers who will be able to carry on effectively in the future. What some of these methods and incentives should be, I shall try to discuss briefly.

Science and technology make up a loose type of partnership, in which the partners divide the work, supplementing one another and, in addition to material success, receive satisfaction in individual accomplishment. The whole structure of getting scientific information and subsequently applying it in useful products and processes is quite complicated. It includes the scientific workers, followed up by our great industrial system based on private enterprise.

The most outstanding of the partners in science responsible for initiation of new developments are the research scientists, inventors, and engineers. They all play an essential part in our technological advance.

The scientists are the producers of raw material—new knowledge—which is subsequently applied in our industrial pursuits. We include in this group of scientists the fundamental workers, predominantly in the universities,

who are continually searching for new knowledge by theoretical and experimental methods. These pioneers are stimulated principally by the desire for new knowledge, having in mind no immediate application of the fruits of their work. Sometimes members of this group deplore any consideration of any practical application, except possibly as a step to pry further into the secrets beyond the existing frontier. The scientific group includes also those more practical prospectors, usually classed as industrial research workers, located in industry and research foundations, who use the same scientific methods to obtain needed information for the solution of specific problems at hand.

Good scientists are, in general, well-trained, inquisitive individuals, and resourceful in methods of seeking the truth. Their part in the scientific partnership need not always be directly or immediately cooperative. Their products—new knowledge stored in technical literature—are drawn upon by others for useful technological applications or as a step for further scientific progress. Scientific discoveries and quantitative data obtained by them may be promptly useful or may not be used for many years. Eventually, however, practically all results find application, and often multiple uses, in the production of new products, processes, and services.

The next partner is the inventor. He devises something new and useful, using existing knowledge. He is naturally an imaginative individual and asks himself, "How can this scientific knowledge be used, or how can I accomplish a certain function with the information which is available?" By "inventor" I do not necessarily mean one who always makes patentable inventions, but one who suggests uses, combinations, and applications of the abstract knowledge

passed on by the scientists. Let us exclude the "nut inventor" from consideration, he being the one who suggests things without regard to their being better, practical, or operative. True inventiveness is an essential characteristic in our scheme of technical progress, and it is found in a greatly varying degree in the technical workers.

Then comes the third group of partners, the engineers, whose duties, talents, and inclinations lie in the development and design of new products and processes so as to accomplish a desired result in the most economical and efficient manner. Again, they usually use information that is at hand and must cooperate closely with others so that their designs will be suitable for tooling, will contain the proper materials, and will meet public acceptance and existing competition. The work of the engineers is mainly development and design, and, although it is not generally appreciated, they carry the greatest burden and responsibility in industrial advances.

The getting and applying of scientific knowledge is not quite so clear-cut as this brief outline would indicate. The research scientist, the inventor, and the development and design engineer are not necessarily separate individuals. The same worker may be a scientist and an inventor. Often an inventor may carry through with his own developments and design. (George Westinghouse, whose birthday we are now celebrating, was a good example of this combination.) Infrequently, all functions may be performed by the same worker. However, experience seems to indicate that at least some specialization is usual and desirable for the best results.

Today, in the esteem and the appreciation of the public, science is in the saddle. The war has been called "a scientists' war" because so many weapons and defense

systems were developed by scientists and used to meet the needs of the new mobile type of warfare. It is not generally realized that science applied by our chief enemy determined the blitz tactics, and we, unprepared, had to fight science with science.

Science alone could not have supplied our gallant boys with the weapons to bring victory. It was teamwork involving all partners, backed up by the wonderful production facilities of the nation. Germany had many good scientists, inventors, and engineers but lacked the organization and industrial resourcefulness to compete with our system of private enterprise when things began to get tough and her handicap of preparedness had vanished.

Popular opinion is responsible for putting science in the saddle, for several reasons. In the first place, each group of partners in science likes to think that its contribution is the most important, and I believe that the scientists and the scientific journals were not at all backward in reporting their accomplishments. Then, popular reporting of scientific work is more newsy than the more prosaic work done by engineers. Finally, the most glamorous accomplishments, such as radar, the atomic bomb, and the proximity fuze, are applications of scientific knowledge more recently acquired, and they are credited mostly to scientists, particularly physicists and chemists, who in special groups actually carried on the engineering development. Probably well over 95 per cent of the activity on these glamorous items consisted of engineering and production. All of them were applications of prewar scientific knowledge. Although a great amount of specific research had to be done, most of the work of the scientists was invention and engineering, and these are activities quite outside their usual field.

Now that we have briefly reviewed the individual partners in science who are responsible for the initiation of new industrial activities, I should like to make some observations regarding the requirements for the immediate future.

There is a general feeling that during the war a great amount of fundamental scientific work was done and that the store of basic knowledge is full to overflowing. This, unfortunately, is not the case, because the workers in pure science were taken from their usual pioneering activities and used to solve pressing war problems in industrial research and development. It is, however, true that the great amount of work done on specific problems resulted in new materials and quantitative and basic data, capable of quite extensive new application in the future.

We need now to revert to the usual sequence of technological development proved by past experience and have the research scientists and professors back at the universities to do their chosen work in fundamental research and the training of men to carry on in industry. This will help overcome the present shortage of technical workers for the important postwar activities. The present college enrollment is enormous, owing mostly to the G.I. Bill of Rights. As a result, many technical workers will be graduated in the next three or four years, but we fear that this will result in more quantity than quality. In spite of the possible further delay in the supply of good men to industry, the most promising students now in college should be located and made candidates for postgraduate study.

Fortunately, the present shortage of technical workers is only temporary. We should now endeavor to meet the requirements for the future by instituting some scheme

of locating individuals with an aptitude for scientific or engineering careers. We should then see that they have an opportunity to take the schooling and should encourage their following scientific pursuits by offering good remuneration and acknowledging their professional status.

The Science Talent Search, which is sponsored by Science Service and Westinghouse, is a wonderful beginning along this line. It enlists the help of teachers in high schools, it works with the science clubs, and it brings forth many promising embryo scientists. However, something more has to be done than evaluate scientific ability, knowledge, and enthusiasm at high-school age. A youth may belong to a science club simply because his best friend does, or he or she may perhaps see a certain amount of glamour in science subjects. Children are fickle at high-school age, and means should be found to determine whether their interest in science will be permanent.

Mr. B. G. Lamme, who was our chief engineer for many years, took great interest in the many college graduates who came to Westinghouse on the training course. He would seek an opportunity to call in each man for a heart-to-heart talk. He did not ask the student's liking or ambitions at the time but would talk about almost everything except his future career. The object of this informal, friendly talk was to swap stories of boyhood pranks and what was of interest in work, play, sports, and so forth, when he was young. Such talks allowed Lamme to classify the men accurately as being good in design, development, testing, production management, application, or research. He repeatedly found graduate engineers who he predicted would not be successful in any branch of engineering, since they seemed to be misfits and should never have taken an engineering course.

As long as a youth is allowed to pick his own course of study—based on the desires of the moment—or is influenced by his parents or the lure of profitable work, the colleges will continue to be wasting effort on a great many misfits. Frequently students in upper classes, and even graduates from technical schools, do not know what their chosen career is all about.

It seems that some scheme of classification and selection such as Lamme used so successfully for predicting the best specialization of graduate engineers would be helpful in selecting the proper college course before training is started. Qualified analysts, I believe, could work out some formulas or interview system that could be used to advantage in orienting prospective college students. Questions and study of biographies, I think, quite clearly show that the natural bent in childhood indicates quite clearly the permanent line of interest.

For the last few years there has been a lot written and said regarding the changes in engineering curricula. Some of the engineering colleges have changed to a five-year course or are contemplating such a step. The main object of this is to have more opportunity to include the humanities in the curriculum. This change has it advantages. Graduate engineers, as a rule, have been deficient in social, economic, and cultural training because of the lack of interest and the intensive schedule of technical subjects that they have to carry. We in industry see the advantage of these changes in curricula but feel that the additional 25 per cent of engineering courses should be partly used to give more training in the fundamentals of science, in fundamental studies.

The unusual success of scientists, especially physicists, who worked really as engineers on war problems I think

is very significant. There is no doubt that their accomplishments were outstanding in the Radiation Laboratory at M.I.T. and at the various centers of activity on the atomic bomb project. Their great success as inventors and development engineers, I am convinced, was the result of their good training in the fundamentals of science. They definitely could do the engineers' development work better than engineers could have done the scientific research required for the various tasks. Physicists, as individuals, are probably no brighter than engineers on the average, but their type of training is characteristically different.

Physicists and chemists in the more advanced courses are taught fundamentals, while the corresponding mechanical, electrical, and chemical engineers depend too much on practical training, empirical formulas, and handbook data, to be really resourceful in invention and development of new things. Engineering today includes many branches such as electrical, mechanical, electronics, aeronautical, chemical, hydraulic, lighting, acoustic, sanitary, and others. Nuclear engineering is just starting. These all involve the application of the various subdivisions of the physical sciences. One who knows and uses the basic scientific knowledge rather than empirical data can be useful in any branch of engineering development. The physicist keeps in mind the fundamental mechanism of scientific phenomena. The engineer has a tendency to work empirically—with gases, for instance, considering them as elastic media, or an electrical current, or a heat-flow problem as a fluid-flow problem, rather than working with the proper physical conception of the mechanism involved in each case.

Empirical data and engineering short cuts do not exist for new applications of science in engineering develop-

ment. They are built by the toil of design engineers who, depending upon experience, transform the products of development engineers into the most practical and economical form for manufacture and use. A more complete training in fundamentals in the college course will surely be beneficial to the design engineers as well, for their great worth and proficiency are acquired as a result of experience after graduation.

Inventors and inventiveness play an important part in our industrial progress. American inventiveness, stimulated by the incentives of a successful and proved patent system, is responsible for much of the better living and working conditions, better products at lower cost, and millions of jobs resulting from the production, distribution, and sale of patented goods. Although American inventiveness now stands out ahead of that of other countries, efforts are being made by a national committee and contests are being contemplated by the Navy to see what more can be done to develop inventiveness in individuals.

The inventor, with his natural intuition for sensing possibilities of using and combining scientific knowledge to create new and useful things, must also depend upon basic scientific knowledge for his working tools.

While we are considering incentives and rewards for accomplishment, we should not forget the scientist and should work out something to reward him for outstanding discoveries and valuable contributions that cannot be covered by patents. These are the things from which industrial advances stem. Attempts in the past have not met with success, but some method based on usefulness or degree of application of discoveries, although delayed in time, might be worked out.

I should like to speak briefly on the technical reporting and dissemination of scientific information, especially in the technical publications of our societies and engineering institutes. In the first place, abstract scientific knowledge is not competitive, and the widest possible publication should be given to all results from research laboratories in order to make them more generally useful. Engineering publications today report many valuable descriptive articles covering engineering applications, improvements, and technical advances in established lines of product. There are, of course, excellent technical articles covering further research in fields already applied. However, there is little said about abstract new data discovered or worked out in other scientific fields. These publications do not keep engineers sufficiently advised regarding pioneering work. Surely this could be done in short abstracts, with references to the original work in scientific literature. If such newsy abstracts were published in engineering periodicals, it should lead to more numerous, useful, and earlier applications.

I hope I may be pardoned if these remarks seem to be too critical of the present training, characteristics, and operations of the partners in science. I realize my viewpoint is that of one in industrial research, and many may feel that the type of training of engineers not in that field should be even more practical than is carried on now in the colleges. We believe, however, that practical knowledge needed for such engineering comes with experience after graduation. Our observations indicate that specialization should begin after graduation. Workers in research and invention and new application of science should continue to keep up on scientific information; designers, industrial engineers, and others should continue their edu-

cation by following progress in their chosen field of specialization.

During this postwar era, there are new horizons in science and possibilities for more rapid progress in its application. Everything possible should be done to meet the challenge and help each group of partners do its essential and supplemental part.

Horizons in Communications

BY

DR. FRANK B. JEWETT
President, National Academy of Sciences

Dr. Frank B. Jewett, *President*, National Academy of Sciences. A brilliant career with American Telephone and Telegraph Company since 1904 has established him as one of the nation's top experts in communications. Served as vice-president and director, Western Electric Company; president and chairman, Bell Telephone Laboratories; vice-president in charge of AT&T development and research since 1925. Awarded Distinguished Service Medal in First World War, also served in Second World War as member of National Defense Research Committee, Office of Scientific Research and Development; of Co-ordination and Equipment Division, Signal Corps; and as consultant to Chief of Ordnance. Member of Committee on Postwar Research and Science Advisory Board. Won Edison Medal, Faraday Medal, Franklin Medal, and John Fritz Medal.

Horizons in Communications

WHEN ONE UNDERTAKES TO FORECAST THE PROBABLE future and picture horizons in communications, two things must be determined at the outset.

In the first place, is one to consider all the varied forms of communication involved in the intricate network of intercourse in our modern world and of their bearing on one another? Or should one confine his speculations to a single form of communication with only incidental reference to other forms insofar as they have or are likely to have a definitive influence on the particular field he is considering?

Even a cursory survey will show that full development of any single type of communication as forecast by its technical and economic possibilities is not something attainable without reference to the developments in other forms of communication or of the limitations that these developments may themselves impose by invasion of field.

A single example from many will suffice to demonstrate this. Both technically and economically it seems clear that great advances are possible in the speed, quantity, and lowered cost of those forms of communication involved in the physical transport of goods or persons. Beyond a certain point, however, these possible advances cannot be realized if the communication of ideas and intelligence is inadequate. The reverse is likewise true.

In the second place, one must decide whether the horizon he is seeking to outline is that of the technically

possible when all conditions favor, or whether it is the horizon of large and dependable social and economic usage; in other words, a horizon within which society has come to utilize and place dependence on that particular form of communication as a regular integral part of its complicated machinery.

An example of this difference of horizons and likewise of the dependence of one means of communication on the development of another and very different form of communication is to be found in the early history of rail transport.

More than a hundred years ago rail transportation had reached a point where relatively high speeds for trains of considerable capacity were clearly attainable. The technical horizon under favorable conditions was therefore extensive. In the enthusiasm it engendered, schedules of train performance were set. They were rarely met until the electric telegraph came into the picture. Before its advent there was no adequate way of conveying the intelligence needed to operate trains satisfactorily in a manner that would ensure reliable regular utilization of the speeds they were capable of attaining. The existing means of transmitting intelligence were slower than the trains.

Telegraphic train dispatching revolutionized railway operation. At a stroke it enlarged immeasurably the utilitarian horizon of rail transportation without, however, changing materially its technical horizons. With its advent, rail transport, particularly for passengers, ceased to be a risky gambling operation when appointment dates were involved. As its use spread and became universal, dependability of train operation became such that the whole business and social structure of the nation began to

alter its form and methods to utilize fully the great inherent technical and economic values of transport.

With these several alternatives of choice available, it has seemed to me that in the few minutes at my disposal the most profitable thing I can do is to devote them to the horizons I am most familiar with, those of electrical communication. Further, because of the shortness of time, I shall consider mainly the horizons imposed by social or economic factors rather than the more alluring and exciting ones presented by purely technical possibilities.

As to these latter, the advances of science and technology in the last two or three decades have been so astounding that in practically every sector of electrical communication there is practically no limit to the distance we either know we can now go or have reasonable expectation of attaining if it is worth while to spend the necessary time, energy, and money on the adventure.

In this respect our present view of distant technological horizons is radically different from that of twenty or thirty years ago. Then for some forms of electrical communication mere physical distances were an unsolved problem. Likewise scientific research had not yet given us the tools with which to attack effectively even the rudimentary beginnings of other types of communication.

If we view electrical communication from the standpoint of a social service rather than merely as a laboratory "stunt," we find it divided roughly into two categories, depending on which of our sensory organs—eyes or ears—are normally involved in conveying to the brain the message being transmitted. Where vision is required in the final act of interpretation, we can give the generic name "telegraphy" to the method of communication and "telephony" to that which employs sound. In making the

division on this basis we need not be concerned with whether the electrical transmission employs wires or radio —these are purely technical matters, where choice is determined by economic and engineering considerations.

Both telegraphy and telephony have one objective in common, to eliminate distance as a factor in communication; within limits to do it essentially instantaneously and, in the case of two-way telephony, in effect, to bring two people face to face for normal intimate conversation.

Under these definitions all ordinary land or transoceanic telegraphy, all printing telegraphy, picture transmission, and television are telegraphy. All two-way telephony and sound broadcasting, whether of speech or music, is telephony.

In general the objective of telephony is instantaneity and without necessity of having a permanent record. Once a channel of communication is established between the correspondents no third party is involved in the act of transmission.

Telegraphy, on the other hand, generally contemplates some delay in transmission and the interposition of one or more agents in the act of transmission.

There are of course exceptions to some of these basic conditions. Most notable are those of true television, where the distant reproduction of a moving scene is instantaneously displayed, or some cases of one-way telephony, where the message is temporarily stored before passing on to the ears of the distant party. True television with sound and two-way telephony with sight are combined telephony and telegraphy.

Now what about the future of the principal applications of these two main subdivisions of electrical communication looked at as social tools?

I think it is safe to say that scientifically and technically we already know how to avail ourselves of all the elements necessary to the giving of any desired service. Some of these elements we have already developed quite fully; some are still quite embryonic, however. The distance further that we go technically appears to be more an economic question than a purely technical one. Undoubtedly further progress in scientific research will indicate other and better ways of doing some of the various things involved and so quantitatively modify any present picture of the future.

Before attempting to examine the distant horizon in detail, one or two general observations seem in order. Technically we know how to combine radio and wire-guided channels in any desired way so that, if engineering considerations alone were to govern, choice of method in each instance would be of the one or more best suited and most economical for that particular problem. In the present state of our knowledge, both wire and radio transmission have certain advantages and disadvantages. In some cases wire transmission is clearly indicated, while in others radio is equally clearly indicated.

In some particulars these advantages and disadvantages seem to involve basic characteristics of the transmitting medium and man's ability to manipulate it to his purposes. To the extent this is so, they seem likely to remain, since our experience so far has shown that almost always—if not always—advances in one art are reflected in the other. The relative advantages or disadvantages have altered with the years but have not disappeared or been reversed.

To the extent then that engineering considerations do not govern in the future, the reason will probably be

found in those man-created things, "vested interests," which we are so prone to perpetuate even when society pays quite a price for the perpètuation.

Let us look first at telegraphy, the oldest of our electrical communication services and, in fact, the oldest general application of electricity.

In essence it is an expedited form of letter service, and there seems no reason to think that where this form of communication is wanted it will be displaced by other methods. For certain types of communication it has one great advantage over ordinary telephony in that exact records of each transmitted message are in the hands of the two correspondents. Many of the technical methods of telephony can be applied (usually in simpler form) to better and cheapen telegraph operation.

The introduction of two-way teletypewriter service in effect combines some of the advantages of both telegraphy and telephony and seems bound to grow with an advancing technology. It is never destined to reach the magnitude of long-distance telephony, however, for very obvious nontechnical reasons.

Telegraphy is nevertheless beset on all sides by competitors. Local telephony has superseded it for the great mass of short quick communications, except where a record is imperative and the post too slow. Even for much long-distance communication where the messages are long, the telephone is a serious competitor unless the necessity of an exact record controls.

Even in its own field of record communication, telegraphy has a serious competitor in the growing cheap airmail service. Its one great advantage is in its speed, particularly where it is possible to use the telephone for

the initial terminal operations of getting the message to and from the ends of the trunk lines.

Taking all of the factors—technical and economic—into consideration, the horizon of ordinary telegraphy as we know it seems to me that of a moderately expanding service in a specialized field of communication. More and more it will tend, I think, to make common use of plant facilities that must be provided in large amounts for other services, particularly telephony.

Two-way telephony seems destined to continue to be by far the largest factor in electrical communication. This is both because of its unique ability to bring distant parties in effect together for normal intimate conversation, and because the whole social mechanism is becoming increasingly dependent on the telephone for its efficient operation.

The goal of ideal telephone service is that of establishing connection between any two persons anywhere, any time, without delay, on demand and to provide them a satisfactory circuit at a reasonable charge, that is, one which will not be a deterrent to usage when such usage is desired. To a large degree this goal is already being approached in this country and at various places elsewhere in the world.

Even today there is no insurmountable scientific or technical obstacle to a substantial achievement of the goal if other factors permitted. These other factors are essentially economic and administrative. As to both, the present scientific and technical outlook gives promise of material aid, so that the horizon does not look unattainably distant. Technology cannot furnish the whole answer, however, nor does its contribution seem destined to be that of some revolutionary new thing. Rather it will be

through meticulous attention to the infinitude of essential items that must be associated together in the complex organism.

Aside from the terminal substation equipment involving the transmitter and receiver, the two great problems of any telephone system are concerned with the trunk lines, which connect the switching offices together and to the terminal substations and with the infinitely vast and complex switching mechanism itself.

Because the social structure is organized as it is with high peaks of personal and business intercourse concentrated largely in a few hours of the twenty-four, a peculiarly difficult problem is presented to telephony. To be satisfactory to the public, any grade of service must be uniform throughout the entire day. This means that in anything approaching the ideal, enough circuits and equipment must be provided to give no-delay service at peak times. Most of such facilities will consequently lie idle during the major part of each day.

From an economic standpoint this is only possible if the costs can be so reduced that circuits and switching mechanism can be provided in great profusion without imposing a deadening load of cost on the total service.

Scientific research and development have already gone a long way in this direction. There is every present prospect that they can go much further.

So far as transmission circuits are concerned, the limiting factor is essentially cost of making available to the public what the scientist and engineer can provide.

When it comes to switching mechanisms, however, other large factors that are fundamentally neither technical nor economic are introduced in the problem of providing a no-delay service for tens of millions of subscribers

calling each other in wholly random fashion. It is not inconceivable that a system could be developed that would permit any one of many million subscribers to dial any other one directly without aid of an operator and with full automatic registration of all data needed for billing. The system would be so intricate, however, that it is most unlikely that the necessary information for operation could be placed in the hands of each user or that they would be able or willing to operate such a system. There is present prospect, however, that a partial approach to the goal can be attained by the extension of direct originating operator dialing.

Further, there is every indication that normal telephone services will be largely extended in many minor situations, such as to vehicles, boats, and so forth, where public convenience indicates a real need. Here again the controlling factors are not primarily technical but economic.

Radio broadcasting has already set the pattern for its future. Further technical developments will doubtless alter the kind and arrangement of circuits and apparatus employed, but there seems little likelihood that the basic pattern will change materially. Originally an intriguing novelty that created an intense public interest, it has become a great industry where reliability of service rather than spectacular "stunts" is a dominant and controlling factor in commercial and plant operation. Twenty-five years of experience have pretty well demonstrated also the proper roles of wire and radio transmissions in the vast flexible complex network.

In addition to being a great industry, radio broadcasting has become a powerful implement in the social and political life of the nation and the world—so powerful, in fact, that grave danger to society might easily result

were it to become the tool of political government. Because of the way in which we here in America have developed it, it is a unique industry in that the ultimate consumer directly pays substantially no part of the cost of the service he receives.

Looking to the future of its social significance, this pattern is probably the greatest insurance we have that it will not become an instrument of oppression and danger. Preservation of it will require unremitting watchfulness, however.

For nearly twenty years now, since the first long-distance demonstrations of the Bell System in 1927 showed its possibilities, television has been much discussed by scientists and laymen alike. From the beginning its ultimate future as a great new social implement has been forecast. So far, however, the horizons have been largely those of possibility and hope rather than those of an established stable service.

A huge amount of technical work has been done in the intervening years, and many brilliant men have devoted themselves to television. War problems have given added impetus to this work, so that at the present time I think it safe to say that technically the art, while still far from perfect, is sufficiently far advanced to forecast a system that would be technically acceptable, at least initially. Further, there is little reason to doubt that expanding science will ensure needed improvements.

Here again, therefore, the controlling factors in creating an industry are essentially economic and commercial rather than technical. The problems to be solved are extraordinarily difficult and will require much ingenuity if television really does contain the germ of a great social service.

In this instance, for example, an obstacle to extensive employment of large-screen television in theaters resides in the cheapness and speed with which motion-picture films can be transported. It is not a factor where there is intense public interest in viewing at a distance actions exactly at the time they take place. It may, however, be the controlling one in economic success where true television is not employed or where synthetic programs are involved.

Likewise, since television service is tied so definitely to broadcasting and its methods, and since a sound-television set is bound to cost more than a simple loud-speaking radio receiver, questions of the probable size and character of the audience to which the advertiser can hope to appeal or the class of articles advertised become important.

On the fringes of all forms of electrical communication, and to a considerable extent as a result of war development, are a large number of variant forms of communication whose horizons appear rather close and promising. Prominent among these are extensive uses of radar and some of the more recent developments in microwave radio. Mainly they are concerned with matters of water or aerial navigation, with increased safety of operation or, as may be the case with trains, better methods of operation. Further, for some of the newer developments in electrical communication or of particular tools developed for it, horizons of use may have been indicated in many new fields.

In the transmission of the electrical impulses that in telegraphy and telephony convey the record of speech messages, astounding progress has been made in recent years in both wire and radio, and the end is not yet in sight. High- and ultra-high-frequency multiplex systems with suitable terminal and repeater equipment have been

developed and are in extensive use commercially. By means of these systems literally hundreds of noninterfering messages can be transmitted simultaneously long distances over a single channel, which can be used at will for telephony, telegraphy, or television.

In recent years a start at least has been made in analyzing speech, picking out a limited number of control characteristics, transmitting the simple impulses that represent these controls, and using them at the receiving end of the line to actuate local equipment to reconstitute speech synthetically. The degree to which the synthetic speech corresponds to that of the speaker is primarily a question of cost and complexity of terminal equipment rather than one of physics.

How far commercial transmission systems based on this method are likely to be developed is uncertain. The fact, however, that the transmitted impulses are limited in number may afford opportunity for solving special problems that might otherwise present difficulties.

While all these new horizons are enticing, they are for the most part, I think, horizons of assistance to other services rather than horizons of new communication services.

In brief summary, therefore, the horizons of electrical communication for the principal uses to which we employ our eyes and ears in the normal transmission of intelligence appear about as follows, for both civil and military employment. The requirements in both these sectors of use are basically the same. The differences that exist are not differences of kind but rather those of importance in elements imposed by differences of usage.

Technically we already know enough so that if occasion required it would be possible under favorable condi-

tions to create a world-wide communication network, which would enable anyone anywhere to communicate essentially instantaneously with anyone anywhere else, either by telephone or telegraph, or for anyone anywhere to communicate a message simultaneously to everyone else in the world.

This would be a "stunt," however, and not a service. It would be incredibly costly and in the present state of the art exceedingly uncertain and unreliable in performance.

Within this horizon of the technically possible is an almost illimitable opportunity for the scientist and engineer to better, cheapen, and increase the reliability of the vast multitude of elements that are involved in a world-wide system of telephone and telegraph communication. It is in this opportunity that the challenge of the future lies, and there is no reason to think that it will not be accepted.

Past experience in communication development, as elsewhere in the evolution of applied science, has shown that large social usage always follows demonstration of technical reliability of a desirable service that can be furnished at a cost that society considers reasonable. No matter how alluring the purely scientific or technical horizons may be, large usage never develops when a high degree of reliability is not assured. The service may be useful and used extensively in emergencies, but it does not become an established integral part of the social or economic machinery in the absence of assurance that, barring infrequent accidents, it will be available at the time its use is desired.

Commentary

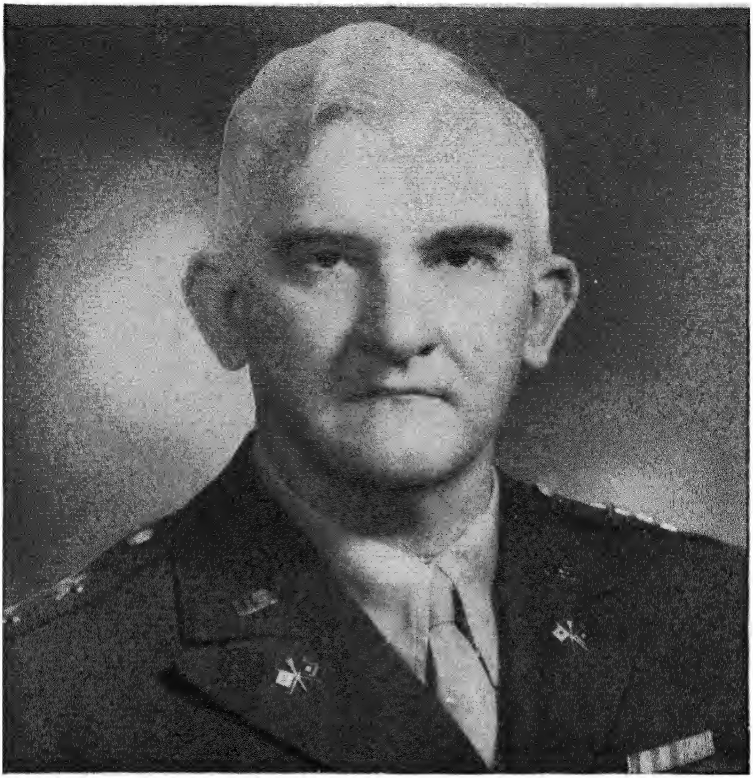
ROGER B. COLTON

Major General, U.S. Army (Retired); Vice-president, Colton and Foss

Dr. Jewett has discussed the subject of electronic communications. It would be superfluous for me to comment on the address of the President of the National Academy of Sciences, but I am sure that if George Westinghouse were here, that address would have interested him greatly.

He would also be glad to know that it was his organization that originated broadcasting in the United States; he would be glad to know that his company, during the war, expended some 25 per cent of its efforts on electronic equipment; he would be glad to know that his organization built the radar sets that detected the Japanese at Pearl Harbor; he would be glad to know that our Army was fully equipped with those radar sets, having 100 on hand and others in storage.

Thus we see, and are glad to see, that the same spirit of research, development, engineering, and production that inspired George Westinghouse lives on in his organization.



Major General Roger B. Colton, U.S. Army (retired), *Vice-president*, Colton and Foss. During the final dozen years of a long military career, directed nearly all electronic research and development for Army. Formerly director of Signal Corps Laboratories, in recent years has had responsibility for all electronic equipment for Air Forces. Awarded Distinguished Service Medal for work as Air Communications Officer of Air Technical Service Command at Wright Field and Electronics Adviser to Headquarters Army Air Forces and Legion of Merit for outstanding services in supplying communication equipment, including radar, to United States Army and many of the United Nations. Member of Interdepartmental Radio Advisory Committee, and delegate to 1934 International Radio Consulting Committee, meeting in Lisbon.

The Golden Age of the Future

BY

A. W. ROBERTSON

Chairman, Westinghouse Electric Corporation

A. W. Robertson, *Chairman*, Westinghouse Electric Corporation. Has been board chairman of Westinghouse and subsidiary companies for 17 years. Left law practice in 1910 to become title officer of Pittsburgh Guaranty Title and Trust Company. Joined legal staff of Pittsburgh Railways Company in 1913, in 1918 had become general attorney of the Philadelphia Company, directing all legal work for Pittsburgh utilities. Made vice-president in 1923, president of the Philadelphia Company, Duquesne Light Company and Pittsburgh Railways Company, 1926. Became Westinghouse chairman in 1929. Director of Canadian Westinghouse Company, Ltd.; Chase National Bank; Farmers Deposit National Bank, Pittsburgh; Reliance Life Insurance Company; and Westinghouse Air Brake Company. Trustee of Allegheny College and University of Pittsburgh.

The Golden Age of the Future

HISTORY DISCLOSES A FEW PERIODS IN WHICH CIVILIZATION flowered into a superior state of excellence. One immediately thinks of the artistic development of Greece with its unsurpassed architecture, temples that we admire and copy to this day, immortal sculpture, literature, and probably painting and music, although we know less of these.

A few centuries later we think of the Roman civilization as one in which law and order first predominated, implemented by authority flowing from a relatively small group of people inhabiting a city called Rome. And to this day that city is symbolic of power and authority and the home of the scarlet robe.

Centuries later there was a flowering during the Renaissance that reminds us of Greece. Again, architecture, sculpture, music, and painting flourished.

Following this period we had less conspicuous but important nuclei of surpassing achievements by smaller groups of gifted men. Music in the hands of Verdi, Wagner, Beethoven, and Brahms took on new glory. Literature flowered into a Shakespeare, and in general the forms of modern civilization began to emerge out of the pages of history.

And so we come to the hundred-year period rounded out by this Centennial. During the past century, humanity has experienced a development and growth—a flowering,

as I think of it—very different from the preceding periods when other gifted men lived. None of these other periods of glory covering the twenty-five hundred years of history altered the material environment of humanity. The Greek temples were built by men poorly fed, ill-clothed, and ill-housed. They did not possess one single thing that we use in our daily lives to keep clean and comfortable. All this is equally true of the Roman soldier and the Roman emperor. The de Medici of medieval times lived in a most uncomfortable palace without any of our necessary comforts.

But today, a strange new civilization in its physical aspects has developed, dominated by the machines man has made. The significance of the machines lies in the fact that they have given men freedom. For the first time in all the ages men can, if they will, with the use of machines have food in plenty. Man has been freed from the drudgery of spending all his daylight hours in taking care of himself as he once had to do. He is now free to move about the earth almost at will. He found mechanical wings. He can project his thoughts across the ocean and have them answered instantly.

All these supreme periods in the history of mankind have developed from the work of a few gifted men. During their lives they stimulated other able men, and as a result something new was added to human experience and knowledge. We celebrate the one hundredth anniversary of the birth of one of these men. It is significant that his celebration coincides almost exactly with that of two other men—Thomas Edison and Alexander Bell—who also brought great gifts to us. During this hundred-year period, the genius of the human race has devoted itself to learning and making use of the newly acquired scientific knowledge.

In a very real sense in this period we have changed the face of the earth. Although civilized man has always lived in so-called "cities," they were not cities as we know them. No other age could build skyscrapers. Even if they could have built them, they couldn't have used them because they had no elevators. The cities of Athens, Rome, and London of ancient times were sprawling communities inhabited by crowds of people who lived and stayed in certain blocks. They didn't move about as we do from one end of the city to the other because they had no transportation and, of course, no water supply, sewage disposal, gas, or electric power.

In recent years our first interest turned from the machine with its gift of freedom to the marvels of chemistry and the composition of matter. We began to make strange concoctions that had marvelous properties. We learned to control germs that formerly had feasted upon our bodies. We learned what to take to kill pain, and anesthetics made surgery possible. Other strange materials began to make their appearance. Some genius had discovered that there were ninety-two elements in the world in place of the four simple elements of earth, water, air, and fire of Grecian times. We began to hear that great power was concealed in the atom, but it was beyond our grasp. We had no harness for it, as we had devised for steam and electricity.

Then came the war and our knowledge of machines enabled us to devise juggernauts of destruction surpassing the nightmare dreams of the insane. And as a climax, we solved the riddle of atomic power and Hiroshima disappeared in flame. The shock affected us also, although we didn't hear the explosion. We still suffer from its effects.

As masters of atomic power and fearful new machines,

we are beginning to wonder if this is truly a golden age. We are beginning to think that our world, which science enabled us to build during recent decades, may have fooled us a little. The shining new automobile was better than a magic carpet. It could carry us over smooth shining roads from pleasure to pleasure. The radio brought into our homes entertainment that few ears had ever heard before. The printing press turned out a steady stream of spot information. Entertainment was to be found at every hand, and there was plenty of leisure, owing to our machine-made freedom, in which to enjoy it. It has been a wonderful holiday, but the sun is setting and darkness may be near.

Reviewing these periods of surpassing glory, it is clear that the human mind in a gifted individual is capable of any conceivable task. It is a safe assumption that no doors are locked against it. In succeeding centuries all will be revealed—perhaps even the secret of life itself. But between that moment of supreme revelation and the present lie centuries of fallow ground.

Although the past hundred years have been entirely different from previous golden ages, there is one point or condition that is common to all periods and that is that man has devoted his genius wherever it has appeared to improving his environment and not himself. The full impact of this fact—if it is a fact and I believe we may accept it as one—is startling in the extreme.

If it is true, man standing in the shade of the skyscraper of 1946 is substantially the same animal as he was twenty-five hundred years ago beneath the shadow of the Acropolis; and the driver in the red roadster, the speedometer showing 60 miles an hour, is twin brother to the man who rode the ass that Christ took for his journey to

Jerusalem. The amusement in our theater of today stresses the same basic emotions and elemental factors as did the theaters of the most ancient times. A mob today is the same wild thing that the Colosseum knew.

The confusion in our national and international thinking points definitely to the conclusion that we have no rules to guide us in the matter of human relations. As human beings, we do not know how we should behave. The merits of one political nostrum after another are proclaimed from the printed page and over the air. We know instinctively that there is something wrong, but we don't know what it is.

We are confronted with advocates of Communism with its individual license, Socialism with its appeal to the herd instinct, and Democracy with power vested in a vague ruler called the people, and the straightforward dictators. Terms about ourselves are never defined. It seems that we are coming into the age of the "common man." The public opinion poll has taken the place of the Delphic oracle and is equally unreliable. We fight for Liberty and the American Way of Life and have no definition to describe them. We are deceived by the masquerade and cannot see behind the mask! Arbitrary power is condemned on every hand, but if it wears overalls it is welcomed.

The eagerness with which all matters pertaining to human institutions and human beings are debated is strong proof of our ignorance of the laws and rules, if any, governing us. We debate the theories in regard to human affairs with the same enthusiasm as the scholastics of old debated religious questions and natural phenomena before they knew anything about science or the laws of nature.

An open-minded scientific approach to the whole prob-

lem of human living without debate would undoubtedly reveal to sufficiently gifted men unsuspected rules and principles of human conduct that would lead to the correct formula for the perfect state and the perfect citizen and a society of good men.

We need desperately to define the true formula for living, or we may all perish. As A. Ganson says in *Gentlemen Preferred:*

> Perhaps man's signal lack is self-improvement.
> All else he betters, excepting only man.

In the next golden age we should learn something about ourselves, so that we may make better use of the marvels that gifted men have provided for us.

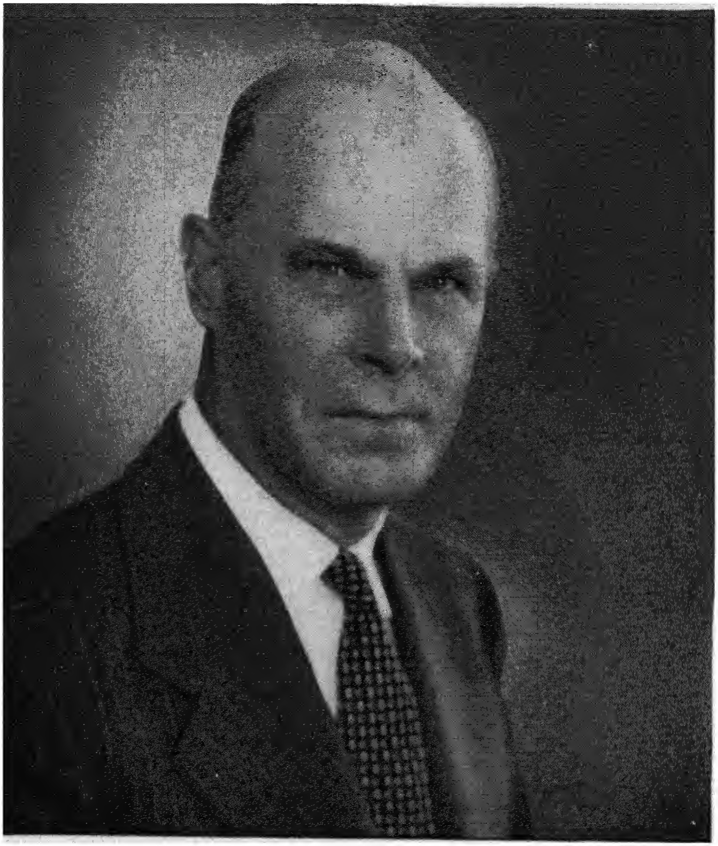
May I express the hope that the study of mankind shall be the subject of the symposium crowning the golden age at the termination of the next thousand years.

Electric Power—The Foundation of Industrial Empire

BY

CHARLES W. KELLOGG

President, Edison Electric Institute



CHARLES W. KELLOGG, *President,* Edison Electric Institute. For more than 40 years an executive with the Stone and Webster organization, including utility managerships in Texas, New England, and the Middle West for more than 15 years. This experience was followed by his work on sales of securities and reporting and engineering. Elected president of Engineers Public Service Company in 1925 and became chairman of board in 1933. Resigned that post in 1939 to become full-time president of Edison Electric Institute. During the Second World War was chief consultant of the Light, Heat, and Power Unit of the Office of Production Management. Graduated as electrical engineer from Massachusetts Institute of Technology, 1902. Member of American Transit Association. Trustee of St. Bernard's School and Teachers College.

Electric Power—The Foundation of Industrial Empire

IN THIS YEAR 1946 WE ARE ASSEMBLED TO CELEBRATE the centennial of the birth of George Westinghouse—great inventor, great business organizer, great American. The scope of his inventive genius was very broad, so broad that I shall limit my brief discussion to the work he did in the generation and distribution of electric power, the results of which form the basis for the universal diffusion of electric energy as we know it today.

It is a curious coincidence that within the six-month period beginning this autumn fall the centennials of three great American inventors, each of whom covered a broad field of inquiry, but each of whom accomplished new things with electricity, and each of whom left his name indissolubly attached to his product: "Bell Telephone," "Edison Light," "Westinghouse Electric." The force with which they all worked, electricity, is thus described in immortal words carved over a portico of the Union Station in Washington:

ELECTRICITY

Carrier of Light and Power
Devourer cf Time and Space
Bearer of human speech over land and sea
Greatest servant of man; itself unknown.

The whole process of the growth of human civilization, from the most primitive days onward, has been the story of man augmenting his own physical powers by harnessing other forces in nature about him. The lever, the wheel, and the draft animal were among the earliest forms of such outside help, but their effect was limited by the physical power and endurance of the animal. Even today with our huge sources of mechanical power, which does not tire with its effort, we still measure them in "horsepower." In this long history of the human race the steam engine was the first great radical advance above animal power. Electric power is the greatest achievement of all in this amplifying of human capability, not only because of the tremendous aggregate size of its development, but because of the ability to transmit it to the point of use and to subdivide it into usable quantities.

Today, on the average in the United States, every industrial workman has at his beck and call the power of seven horses, which, unlike the animal variety, never falter, require no time out for feeding and rest, and are so much cheaper to operate! This horsepower per man in industry has grown 58 per cent even in the fifteen-year period ending in 1944. That this increase in power per man is closely allied with the productiveness of industry is indicated by the fact that during this same period the real weekly wages of workmen in industry (that is, money wages adjusted for the increased cost of living) have grown 63 per cent. Furthermore, the earnings of workmen in industry in our country, compared to their counterpart in other countries, can be shown to bear a close relation to the respective amounts of mechanical power per man in industry in the countries compared.

With this background let us return now to the inven-

tors whose discoveries produced it. Since the wonders of communication that Alexander Graham Bell developed were produced with tiny amounts of electricity, he naturally falls out of a discussion of power.

Most of the great inventions of the past have been based on experiments and studies by earlier observers, and this was definitely the case with electric power. The principle of electromagnetic induction, which is the basis of all generation of electricity for distribution today, was discovered by Michael Faraday in 1837. Building on this principle, electric dynamos had been built by Gramme as early as 1870, and later by Brush and others; but the first incandescent-lighting central generating station was built by Thomas A. Edison in 1882.

Without precedent to guide him, he developed a low internal-resistance, direct-current generator, for maintaining constant voltage on underground distribution lines of his own devising, and, crowning achievement of all, invented the incandescent lamp, the first flameless light, which could be turned on and off at will and would run for hundreds of hours without burning out. He also invented a meter for measuring how much electricity the lamps consumed, thus making it a commercial business. He covered in addition, as they were not then in existence, fuseblocks, fuses, cutouts, switches, and special circuit breakers. The lamp base and socket he designed are still standard today. He was the father of central-station electric service.

The original Edison plant, on Pearl Street in New York City, and its counterparts that sprang up in many other cities in the early eighties of the last century, were regarded as lighting companies. They were known as Edison Electric *Illuminating* Companies, and the first country-

wide association of the new industry, founded in 1885, was the National Electric *Light* Association.

With the growth in the load on these first central stations, with the use of electricity for power as well as light, with the constantly increasing distance of the load from the central station, the industry encountered difficulties with transmission and distribution. With the relatively low voltage at which the direct current had to be generated to be safe for use by customers, substantial load growth meant either a fabulous investment in copper conductors or the necessity for many relatively small generating stations or both. This fundamental dilemma was solved by George Westinghouse, through the development of the alternating-current system, which is used throughout the world today.

In the earliest days of the industry, Ohm's law was thought of in terms of the simple straight-line ratio, that the current was the voltage divided by the resistance. When, however, loads and distances greatly increased, it became evident that the important relationships of Ohm's law were the second-degree factors—that for a given load the line loss varies inversely as the square of the voltage. What was needed, therefore, was a system wherein the transmission voltage should be high and yet retain the possibility of the use of the safe 110–220-volt pressure for the customer's premises. Like "belling the cat," this problem was easier stated than solved. It required the perfecting of an alternating-current generator, the design of a satisfactory transformer, adequate insulation for the higher transmission voltages, and the design of a satisfactory alternating-current motor. To cap the climax, alternating current brought in its train all the headaches of lagging currents and low power factors. Two other neces-

sary details were the development of an induction meter and of a machine for converting alternating to direct current for use in electrolytic and other processes where such current was essential.

This was a large order; but, convinced of the soundness of the principles involved, Westinghouse tackled it with characteristic vigor and system, surrounding himself with the best research brains of his time. The Westinghouse Electric Company was organized by him in January, 1886, to manufacture and promote the use of alternating-current system equipment. In rapid succession the transformer was patented by Stanley in 1885, the split-phase induction motor by Tesla in 1888, and in the same year the induction meter by Shallenberger—all these being members of the Westinghouse team. The first split-phase motor was not entirely satisfactory, and it was not until 1892 that the polyphase induction motor was perfected, the long intervening period of 4 years being required to work out a complete polyphase system of generation and transmission.

In 1890, Westinghouse built a small 100-horsepower, single-phase, alternating-current plant at Telluride, Colorado. The voltage was 3,000 and the transmission distance was only 3 miles, but the amount of copper required for the transmission line was very small, about one-hundredth as large as was needed by the direct-current plant proposed by Edison in competition. The success of this plant led to the adoption of alternating current for the first Niagara Falls plant, where Westinghouse installed three 5,000-horsepower, polyphase, alternating-current generators in 1893. These machines are the forerunners of modern hydroelectric generators of well over 100,000 horsepower.

Westinghouse continued his inventions for electric power systems far beyond the point of establishing the alternating current. The rotary converter for changing alternating into direct current was perfected in the late nineties; but going beyond that he started from the mercury-vapor lamp, which was invented by Hewitt in 1912, and put his company into the field of mercury-arc rectifiers. More than 5 million kilowatts of these rectifiers were built during the late war, and without them the great aluminum output required for our air armada would probably have been unattainable.

He also performed years of work, beginning in 1895, in the perfection of the horizontal steam turbine, which is practically the sole form of steam prime mover for electric generation today. In applying the turbine to driving the alternator, such fundamental matters as the stationary armature, speed, governing, voltage, and so forth were worked out by Westinghouse on a basis that still influences the design of our modern equipment.

Looking back now it is easy to see that, without the alternating-current system, the size and scope of our present-day electric power systems would be quite unthinkable. The development of the years has shown the greatest economy to result from generation in large stations. Without alternating current, and consequent high voltage for transmission, it would be impossible to carry the power away from such large stations. With the direct conveyance of power through the heaviest leather belt, traveling a mile a minute, it would require a belt nearly two-thirds of a mile wide to transmit the output from the largest modern station; but with alternating current at 220,000 volts this power can be safely carried away over three wires the size of your thumb.

The great interconnected networks of high-tension transmission lines that carry power from great stations, both steam and hydro, to load centers some hundreds of miles away, and which make possible the relaying of huge blocks of power in case of breakdown at any given point, would all be impossible without alternating current.

Equally impossible, without this basic system, would be the furnishing of metropolitan-quality service to thousands of small villages and to more than 8 million rural customers throughout the country.

In distribution throughout even urban areas, the beneficial effect of alternating current still goes marching on. At the turn of the century the high-voltage distribution about cities was at 2,200 volts. This involved only one-hundredth of the line loss that would occur with 220 volts, but when, with the passage of time, loads became too heavy to be carried satisfactorily at 2,200 volts, substations fed by 13,200-volt lines were dotted about the city. Now, normal distribution is itself being stepped up to 13,200 volts, with no loss in safety, with a further cut of thirty-six-fold in line losses, and the consequent ability to improve voltage regulation and to eliminate countless substations.

So fundamental has this matter become with the electric utility companies that for many years past the plant investment in distribution (using that word in this case to include the entire process of getting energy from the generator to the customer's premises) has become two-thirds of the total plant investment—an amount fully justified by the facts that without it many millions of our population would be unserved and that generation at large economical plants or distant hydro plants would be impracticable.

Finally, without alternating current and without the great network of transmission lines that its use made feasible, the great production of power for the war effort, always ready when and wherever needed, would have been impossible. Despite the great development of the electric service in its first 56 years, energy sales in the United States nearly doubled from the beginning of the war to its peak, that is, from 1939 to 1944.

The benefits to the nation from the general diffusion of electric energy into its remotest corners are far from being confined to the manufacturing industry. The lightening of household and farm chores by the tireless servant, electricity, has revolutionized everyday life. The drudgery of washday, the labor over a hot kitchen stove, the pumping and hauling of water, the washing of dishes and many similar tasks, which the homemaker toiled through for centuries, can now be made easy in millions of homes in our country, thanks to what electricity can do. The brightening of the long, dark nights by safe, flameless electric lights, the ability to preserve otherwise perishable food, the health and comfort of air conditioning, all combine with the laborsaving to make electricity indeed the "greatest servant of man." Without what experimenters in the late eighties called "Westinghouse current," these blessings would have been largely confined to city dwellers.

In my opening paragraph I referred to George Westinghouse as not only a great inventor but a great American. What his inventions have meant to the people in the diffusion of electricity among 34 million customers, to our homes, stores, offices, and factories, has been but briefly sketched. Of equal value to us as a nation, if we have the sense and ability to follow it, is the example his

life affords of those traits of ingenuity, self-reliance, determination, and industry, which have made our nation what it is.

His keen foresight of the possibilities of the alternating current in 1886 was a stroke of genius, but the courage and persistence with which he followed up his vision during the following seven years, until the soundness of his judgment had been proved a reality, were acid tests of true character and greatness. During this period he had to face the determined competition of the established majority in the electric-service field, and the struggle was enough to daunt any but the stoutest heart. Mankind today is the beneficiary of his steadfast faith in his bold conception.

In addition to his creative imagination, George Westinghouse possessed tremendous energy. During the decade of his greatest creative power he took out 134 patents, over one a month, while at the same time stimulating and directing the work of many other inventors and carrying forward the financial and administrative organization of several companies, both in this country and in Europe.

Westinghouse was not merely an inventor; he was a great manufacturer and builder. The principal companies he set up to manufacture the products of his fertile mind, the largest of which is the Westinghouse Electric Corporation, are still functioning today as an important part of the nation's industrial system, with combined assets of $527 million. He devoted his energies principally to his companies rather than to personal enrichment and died in moderate circumstances.

It should not be gathered from my last remark that Westinghouse was improvident or inept in financial affairs. On the contrary, his financing was on a par with

his other work. From the start of his inventing career he had consistently undertaken the manufacture of the products of his inventions and had made money in the process. The bankers of his time were naturally unwilling to put money into what they would have considered an untried business without retaining a dominating position in its management. This condition seemed intolerable to the free spirit of George Westinghouse and was therefore refused, but it placed on him the burden of doing his financing from his own resources or from funds advanced without conditions by men of wealth who had confidence in him. In the last decade of his life he received a striking public recognition of his probity and integrity in his designation (along with Grover Cleveland and Morgan O'Brien, presiding judge of New York State's highest court) as one of three public trustees of the entire stock of the Equitable Life Assurance Society. This trusteeship finally eventuated in mutualization of the Equitable Life, which now has nearly 4 billions of assets and last year paid its policyholders a dividend of $50 million.

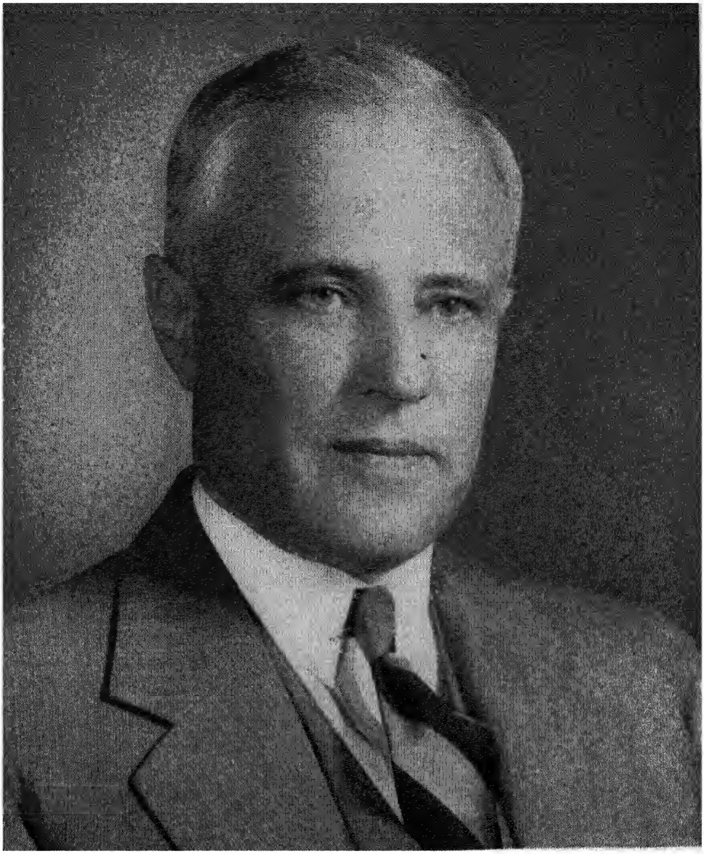
In commemorating the life of George Westinghouse, which began a hundred years ago, we express amazement at what he accomplished and deep gratitude for his great contribution to our common life and we draw high inspiration from the qualities of mind and heart of this great American.

Scientific Progress—Insurance against Aggression and Depression

BY

DR. KARL T. COMPTON

President, Massachusetts Institute of Technology



DR. KARL T. COMPTON, *President*, Massachusetts Institute of Technology. One of nation's most distinguished educators, conducted secret scientific work in Pacific during war. Awarded Rumford Medal by American Academy of Arts and Sciences, 1931. Has served as consulting physicist for Department of Agriculture; chairman of new products committee of New England Council; and member of governing board of American Institute of Physics, Science Advisory Board. Former president of American Physical Society, American Association for the Advancement of Science, and Society for the Promotion of Engineering Education. Member of advisory board, Bartol Research Foundation and Rockefeller Foundation. Trustee for Memorial Foundation for Neuro-Endocrine Research, Boston, and Brookings Institution.

Scientific Progress—Insurance against Aggression and Depression

SOME WEEKS AGO, WHEN IT WAS SUGGESTED THAT I speak on the subject, "Scientific Progress—Insurance against Aggression and Depression," I cheerfully accepted. When, however, I sat down seriously to outline the address, I quickly realized that I had undertaken far more than I could deliver. I felt, and still feel, quite inadequate to the task.

What I shall undertake to do is to try to analyze the problem into some of its more fundamental aspects, somewhat after the manner of an engineering analysis. It is possible to point out the various groups in the country who have major interest, responsibility, and opportunity, and it is possible to point out what may be done in each of these groups by way of implementation in order that they may deliver the desired results.

First, to provide the setting, let me comment on scientific progress with special reference to its rate of development. It is trite to remark upon the rapidly increasing tempo of scientific progress over the past decades and as reasonably extrapolated into the foreseeable future. This increased tempo arises from several factors. In the first place, new tools of great power are continually being

devised, and every new tool applicable in scientific research tends to increase the rate of progress. In the second place, methods for conducting research, especially through cooperative organization and world-wide exchange of information, have a powerful accelerating effect. In the third place, every great success of science in peace or in war that profoundly affects the public leads to increased public awareness of the value of science and generally to an increased public support of scientific work. Finally, I believe, is a very fundamental fact arising from the interrelationships among various scientific facts and fields—the more scientific facts or principles that are known, the greater is the opportunity for finding some combination of previous scientific knowledge that can be used to make some new scientific advance. So, in a rough sort of way, it would appear that the theoretical upper limit to the rate of scientific progress would increase almost exponentially with the amount of scientific knowledge that has at any given time been accumulated.

But there is another interesting aspect of this tempo. This is that in any given field scientific knowledge does not increase at a smoothly accelerated rate, but increases by spurts. We can almost ascribe to it the term devised by Sir Isaac Newton in his incorrect theory of light, namely, "fits and starts." Scientific progress certainly does proceed in fits and starts, and every one of these sudden spurts is due to the development of some new idea, or some great discovery, or some very powerful tool, which suddenly opens the door to another great storehouse of nature's secrets.

Some of us can remember, just before the turn of the present century, when there was a general feeling in physical science that the subject had been pursued prac-

tically to its terminal point and that very little remained except to make physical measurements to an accuracy described by one or two more decimal points. This was at the end of a great era of scientific development based upon the principles of thermodynamics and electrodynamics. This era in turn had followed upon an earlier productive era based on the principles of dynamics, notably upon Newton's laws of motion. But even at the end of the great era of thermodynamics there were on the horizon a few gleams of the great visions that have so rapidly opened up in the fields of electronics, and of nucleonics, which have now opened up vistas for exploration far exceeding any ever before envisaged.

In no aspect of science is the increasing tempo of progress more significant than in the fields of applied science. For many centuries the principal applications of science were the work of individual inventors, like Archimedes, or Watt, or in our lifetime, Edison and George Westinghouse. But it was also within the lifetime of most of us that industrial research laboratories came into being, and in fact the original research directors who organized some of the greatest of these laboratories are still actively with us. In these laboratories industry has rapidly developed cooperative methods for applying science to meet every variety of human need and desire. And in many ways the development of methods of cooperative group attack on problems of applied science has been just as significant as the developments of science themselves.

The Second World War brought on still another development, not new in principle but entirely new in the scope of its application and the perfection of its organization. I refer to nationwide attack on important scientific problems, in which individual inventors and scientists,

the organized research laboratories of universities and of industry, and the various departments of governments, like War, Navy, Commerce, and Agriculture, have all combined to bring the entire resources of the country to bear on import problems. I need only to mention radar, rockets and guided missiles, atomic energy, war medicine, to illustrate what I mean.

Now let me take up more specifically the question of scientific progress as an insurance against aggression and depression. Who is it that is interested and responsible in having this insurance? There is fundamentally just one answer, namely, Mr. John Q. Citizen, individually and collectively. He wants security against aggression in order that he may live his life as he wishes without outside interruption. He wants security against depression—that specter of economic disease which from time to time invades the country, reduces his wages and his opportunities for employment and enjoyment, and, for reasons that he cannot fully understand, makes him the prey of circumstances over which he apparently has no control. Certainly Mr. John Q. Citizen, individually and collectively, is the person with greatest interest and responsibility in the subjects of aggression and depression but, individually and collectively, what can he do about it? In order to answer this question it is necessary to look to some of the organized groups through which the collective Mr. John Q. Citizen operates.

Consider first the responsibility for insurance against aggression. Mr. John Q. Citizen assigns this responsibility to his government, and especially to the Departments of War, Navy, and State. We can say that the government has an AAA priority of responsibility for insuring our country against foreign aggression, and that, while other

groups like industry and universities have an interest and should cooperate when called upon, the responsibility for insurance against aggression is squarely up to the government (of course, to the extent to which Mr. Citizen backs up his government).

When we come to responsibility for insurance against depression, however, we find that this responsibility is more divided and, so far as I can see, government, industrial management, and labor all share about equally the responsibility to do everything possible to protect us against depression. It is the responsibility of the government as the official representative of John Q. Citizen. It is the responsibility of industrial management and of labor because they have the major stake in profits and employment and are the first to be hit in any depression.

If we turn next to an analysis of the opportunities that the various groups have to provide insurance through scientific progress against aggression and depression, we can, I think, make our analysis somewhat as follows. In the field of fundamental research I believe that past experience, future trends, and the whole logic of the situation would arrange the groups in about this order of priority of opportunity. I should assign priority AAA to the universities, AA to industry, A to government, and B to labor. In the field of applied research and development, I believe the priorities would be industry AAA, government AA, universities A, and labor B.

Next, let me turn to the subject of implementation: what can be done by these various groups to implement their activities so that scientific progress can be made that will provide a healthy insurance against the dangers of aggression and depression? This is the most important feature of the problem.

The government has been active in science in two general categories: first, through its permanent scientific bureaus and, second, through its calls for scientific assistance in times of emergency.

There are approximately forty scientific bureaus in the government that are principally concerned either with the rendering of informational service to the public or with the enforcement of regulations in order that various private activities of a technological character can operate with a minimum of interference and a maximum of efficiency in service to the public. There are in addition the various departments of the Army and bureaus of the Navy that are responsible for the development and production of military weapons. All these governmental agencies render essential services. Their healthy operation is necessary for the efficient operations of agriculture, industry, business, and, in fact, every aspect of our national life. These agencies should be supported with funds adequate to carry on their essential operations, and there should be continual review to ensure their operation with proper efficiency.

If we turn to the other aspect of the government's activities in science, however, we find a peculiar and significant fact, namely, that the government has turned to the scientific resources of the country for help in times of great national emergency but, with very few minor exceptions, it has not called upon them for help, except in times of great emergency. The record is very significant.

It was at the time of the Civil War, in 1863, that Congress passed an act establishing the National Academy of Sciences, and this was approved by President Lincoln as a measure of assistance in that time of national emergency. The next great call for help came just before the

First World War, when in 1916 President Wilson by executive order requested the National Academy of Sciences to establish the National Research Council as an instrument of national preparedness. The next move was in the depths of the great depression, when in 1933 President Roosevelt appointed the Science Advisory Board, which assisted the various departments of government to reorganize their scientific activities to salvage as much efficient performance as possible in the face of the drastically reduced governmental appropriations. The next move came in June, 1940, when, with Europe ablaze in war and grave danger that our nation might become embroiled, President Roosevelt set up first the National Defense Research Committee, and one year later enlarged the program by adding a Committee for Medical Research and combining the two under an Office of Scientific Research and Development. It was this agency, generously provided with funds and calling upon the entire scientific resources of the country, that organized, carried through, and coordinated a great part of the program of research and development for the production of new weapons and war medicine so effectively during the Second World War. In 1942, when the sudden Japanese attack had cut our lifelines to the supply of natural rubber, President Roosevelt appointed the Baruch Rubber Survey Committee to recommend a national program to meet this emergency.

Why is it that, with these lessons on the power of science as an agency for the public welfare, the government has never similarly attempted effectively to mobilize and support the scientific resources of the country for the advancement of standards of living in times of peace and prosperity?

Apparently this question has arisen in many minds,

and we now have evidence of a desire on the part of various agencies of government to see that scientific progress is more adequately supported than in the past and that the scientific resources of the country are in fact mobilized, with necessary implementation, to contribute to national welfare generally.

Most significant in their scope and possibilities are the two pieces of legislation now before Congress: the one to establish an Atomic Energy Commission and the other to establish a National Science Foundation. We are all so familiar with the nature and objectives of these two pieces of legislation that there is no point in my discussing them now, except to say this: the Atomic Energy Commission or its equivalent is an absolute necessity, not only for the future safety of our country, but also in order that the country may benefit from the possibilities that can now be visualized from the future advances in nuclear science and their applications to a very wide range of objectives involving national security, industry, health, and agriculture. If ever any legislation was in the "must" category, this is an example. *If Congress should fail to pass adequate legislation during this session, it will be a catastrophe and a disgrace and will leave the country in a period of doldrums where those who have constructive programs in mind will not have authorization or means to go ahead.*

The legislation proposing to set up a National Science Foundation is aimed at wide objectives, as you know: promotion of progress in science and a program of scholarships or fellowships in order that the scientific talent inherent in the population may have full opportunity for education and demonstration. Both for security against aggression and security against depression there is no element that is more important than to have the most

adequate possible complement of able, well-trained scientific personnel in our country. This is more important in the last analysis than laboratories or factories because, without scientists of high caliber, laboratories will be only a delusion and a waste of money, and factories will before long become obsolete.

Within the War and Navy Departments there are also postwar movements that are highly significant and desirable. Both of these agencies recognize the advantage of maintaining the teamwork between civilian scientists, industry, and the armed services that was so effective during the war. Both are taking steps to perpetuate this teamwork. These activities are somewhat different from those of the Office of Scientific Research and Development during the war, because the latter had to be limited to objectives that showed reasonable promise of becoming useful during the war itself. Now, however, the sights are lifted to the future, and quite advisedly the program is on a more fundamental basis and in many aspects is far less confined by rules of military secrecy. Notable among these activities are those of the Manhattan District, which of necessity has to shoulder the responsibility of carrying on the atomic energy program until Congressional legislation for some permanent agency is enacted. A fine job of supporting fundamental research is being done by the Office of Research and Inventions in the Navy Department. The Air Force is planning a somewhat similar program. All the military departments and bureaus are alert as never before to the importance of basic research and forward-looking development. General Eisenhower's establishment of a general staff position for research and development and the Vinson Bill for the Navy are significant moves.

All these moves on the part of government are in the right direction and deserve wholehearted support of every John Q. Citizen as insurance against aggression and depression.

Industry's great role in applied science has been to seize upon promising ideas for commercial exploitation with vision and avidity and to develop them with great skill into desirable products suitable for manufacture and sale to the public. Industry has also developed methods for shortening the time lag of the transition from laboratory to factory. The war afforded many illustrations of this speed-up, where the old motto "from research laboratory to freight car equals seven years" could well have been stated in terms of seven months rather than seven years.

While every industrial research laboratory must in the last analysis justify itself to the board of directors by its contributions to the business of the company, nevertheless it has been recognized by the most forward-looking companies that it is appropriate for them to engage in a certain amount of fundamental research that does not have an immediate practical objective in view. There are several reasons that contribute to this attitude and which are responsible for a rapidly increasing emphasis on it at the present time. One of these is that the highest type of productive research man cannot be retained by the companies unless he has some reasonable opportunity to work on subjects that incite his scientific curiosity and ambition. Another reason is realization that out of this fundamental research very frequently come ideas that can have a practical application. A final reason is that a company may wish to keep itself well informed and advised regarding new scientific developments that are being principally carried on elsewhere but in which the

company may wish at some time to enter in a major way when some attractive opportunity presents itself. A good illustration is the action of a number of industrial companies at the present time to engage or cooperate in some aspect of research in nuclear science, even though it is recognized that the great government-supported laboratories and the leading educational institutions are carrying the major burden of scientific development and will undoubtedly continue to do so for a long time in the future.

Associated with this factor is the undoubted fact that industrial management has become more liberal in the definition of its responsibility to its stockholders in defining the limitations of its research activities. How frequently some of us who have felt the responsibility or the urge to try to induce industrial companies to undertake a more active program in purely scientific research, either in their own institutions or through financial contributions to educational institutions, have been met with the reply that this would not be consistent with the responsibilities of management to the stockholders! Now in very many cases the management realizes that its responsibility to the stockholders cannot adequately be discharged over a long term without vigorous support of the scientific research that provides the basic opportunities for industrial research and manufacture of new products for the future. Even those agencies which have long been noted for the prudence of their financial policies and which have even had prudence forced upon them by governmental regulation—businesses like life insurance, trust companies, or investment trusts—have recently become active in advocating the use of at least some small portion of their assets to investment of a venture-capital nature. There is the same basic relation in venture capital on the portfolio

of an insurance company as there is to a budget item for fundamental research in the program of a manufacturing organization; both are investments in the future and insurance against obsolescence or against the disappearance of future opportunity.

Finally, the attitude of industry as regards scientific research has become notably more cooperative. This is shown in many ways. A large number of the leading food companies have cooperated to establish the Nutrition Foundation for the support of fundamental scientific research in nutrition. Similar examples are the Sugar Foundation and the association of many of the great life insurance companies to support fundamental programs of research on various important aspects of health and disease. It is a movement that has received a notable impetus as a result both of the depression, which emphasized its need, and of the war, which demonstrated its possibilities.

Still another illustration of industrial cooperation for the common end of advancing scientific knowledge is found in the recent attitude of companies in contributing funds, either as gifts or through liberal contracts, to educational institutions or other nonprofit-making research organizations engaged in scientific research along promising lines. One group of companies has contributed liberally to education and research in the subject of food technology. Another group has contributed to the development of a program of education and research in the new field of gas turbines and jet propulsion. A number of companies are contributing funds to various university groups that are setting up extensive programs in the field of nuclear science and engineering. There are many other illustrations. In none of them, so far as I know, has there been involved any very special or selfish benefit to the con-

tributing company. Its principal interests are to have the scientific field advanced, to be kept very promptly informed of all new developments, to have an adequate supply of young scientists educated in these fields as a reservoir for future possible employment, and in general to be closely in touch with these developments pending the time at which the companies themselves may wish to engage actively in certain new aspects. This type of cooperative support of scientific work is an illustration of the more liberal attitude of management and of the realization of the great possibilities in cooperative effort.

Let me turn briefly now to the interests of the labor element in industry. Traditionally labor has feared one aspect of technological progress, namely, the introduction of laborsaving machinery or methods. But I believe it is possible to draw a general conclusion to which I know of no exceptions. It is this: Whenever any regulation or code or other obstacle in agreement or legislation stands in the way of utilizing the most advanced and improved techniques of production, or of erection and assembly, or of design, then these restrictions act to the immediate disadvantage of the public and to the ultimate disadvantage of labor. *More employment and better pay for less hours of work can be attained only if every advantage is taken of technological progress to produce the best possible product at the lowest possible cost. Both logic and experience over any considerable period of time have proved this statement. Labor has its great stake, along with all the rest of the population made up of us John Q. Citizens, in scientific progress.*

Turn finally to some of the problems and trends in the universities. No one can maintain the thesis that the universities are the sole source of basic new scientific knowledge, but I believe everyone must accept the fact

that they have been and will continue to be a major source. There are many logical reasons for this, such as independence from practical directives, presence of generation after generation of eager graduate students to provide continual fresh man power, supplementing the abilities of the staff, and the appeal that the relative freedom of university life makes to men of scientific bent. But whatever the reasons may be, as well informed a person as Roger Adams, in his presidential address before the American Chemical Society some years ago, said that 95 per cent of the products of American chemical industry had their origin in university laboratories. Somewhat the same thing is true in the field of electronics. It is wholly true thus far in the new field of nuclear science and atomic energy. It is almost wholly true in the field of medicine if we include the great hospitals and medical institutes under the broad designation of "university."

What is important for our purposes is not to belabor this point, but to call attention to certain significant trends in university research as to its organization and support. For twenty or thirty years scientific research has held a high place in our educational institutions. It will hold a higher place in the future. For considerably less time research work has had a recognized role in our engineering departments. Here, in general, research has not reached the same levels of importance, advanced character, or expert handling that it has attained in the scientific departments, but there is now a very powerful trend in our engineering schools to increase emphasis on graduate work and research, and to raise their standards.

The most important new development in our universities is the emergence of the recognized "research program" as differentiated from the multiplicity of more or less un-

related "research projects." These research programs are enterprises built around very important objectives and generally involve the cooperative effort of men from various departments and with various specialties. They involve some sort of special organization within the university that is different from the ordinary department because they are not particularly involved with curricula or degrees, although they may contribute to both.

There are illustrations of such research programs in many educational institutions, all of them having in common the following factors. A great opportunity in scientific research is recognized. A cooperative organized program is set up to achieve results in the most expeditious and efficient manner possible. Combined with the ambitions for the discovery of new knowledge is the responsibility for the training of research workers who will be in demand by industry, the government, including the armed services, and other institutions in these particular fields. Very substantial financial resources are required, in many cases annual funds greater than those which supported whole departments of the institutions in the prewar days. The source of these funds has of necessity to be found in the other groups that we have considered, namely, government and industry, which recognize the importance of these fields for their own legitimate purposes and whose more liberal policies, designed to meet the needs of the situation, are developed to permit such support of scientific research programs at their source in the universities.

In conclusion, it seems to me that the foregoing analysis of the situation and trends in the field of science justifies us in looking forward to the future with a considerable degree of faith and enthusiasm. It is a recognized axiom of biology and of sociology that any organism or organiza-

tion that ceases to develop is thereby on the road to decay. Vigorous development is an index of survival. I think we can certainly say that, insofar as science is concerned, we are now in an era of vigorous development, both of science itself and in the techniques of organization, administration, and support, which form the environment in which scientific progress can be made.

Two things seem to me to be essential if we are to realize the values for security and for prosperity that can come out of this program. One is that the trends that I have described must be encouraged, supported at every turn, increased in scope, and, by general public education, carried on with increasing understanding and support of Mr. John Q. Citizen, the public.

The other important point is that scientific work and scientific workers and scientific institutions cannot survive and prosper unless the general environment is favorable. Like the saying, "No man liveth to himself alone," science does not live to itself; it only lives as it contributes usefully to other aspects of society, and it only lives if certain other essential aspects of society are in a healthy state to provide a favorable environment. These other aspects of society include many of the subjects that are most prominently before the whole world today. They include such matters as international peace, the healing of the wounds created by the war, the relations between management and labor. They include governmental policies, such as the extent to which Mr. John Q. Citizen is to be regimented, or to which he is to retain a high degree of freedom of opportunity and initiative. They include the financial policies, which, if unwisely handled, can bankrupt the nation or, through inflation, lead to the wiping out of all the reservoirs for free enterprise.

So those of us who are greatly interested in the contributions that science can make to national welfare must have also an intelligent and effective interest in these environmental aspects, which affect not only the opportunities for scientific progress, but every aspect of our national life and individual happiness.

Finally, I would pay a tribute to the Westinghouse Electric Corporation itself, and to its Educational Foundation, which through sponsoring and making possible this Forum have by that very act made a most significant contribution to the subject of my address, "Scientific Progress—Insurance against Aggression and Depression."

Mr. Robertson, Mr. Price, Mr. Smith, and your colleagues: As the final speaker on this great program may I presume to speak on behalf of all your guests. I can do so with assurance, because I know the sentiments of this gathering. We have, during these days with you, received an intellectual treat and a spiritual uplift. We have greatly enjoyed the opportunity of again renewing our friendships. We have greatly appreciated your hospitality.

It is said that a man should be judged not so much by his performance in the line of duty as by his performance beyond the requirements of his duties. This Forum, and the entire program of the Westinghouse Educational Foundation, are evidence of imagination, courage, wisdom, and desire to contribute to public welfare beyond the mere requirements of corporate performance, which we applaud; and for this opportunity of participation, we are grateful.

Through this Forum, science and life in the world have received new impetus and inspiration for better things. Through it the spirit and ideals of George Westinghouse take on fresh life and influence.

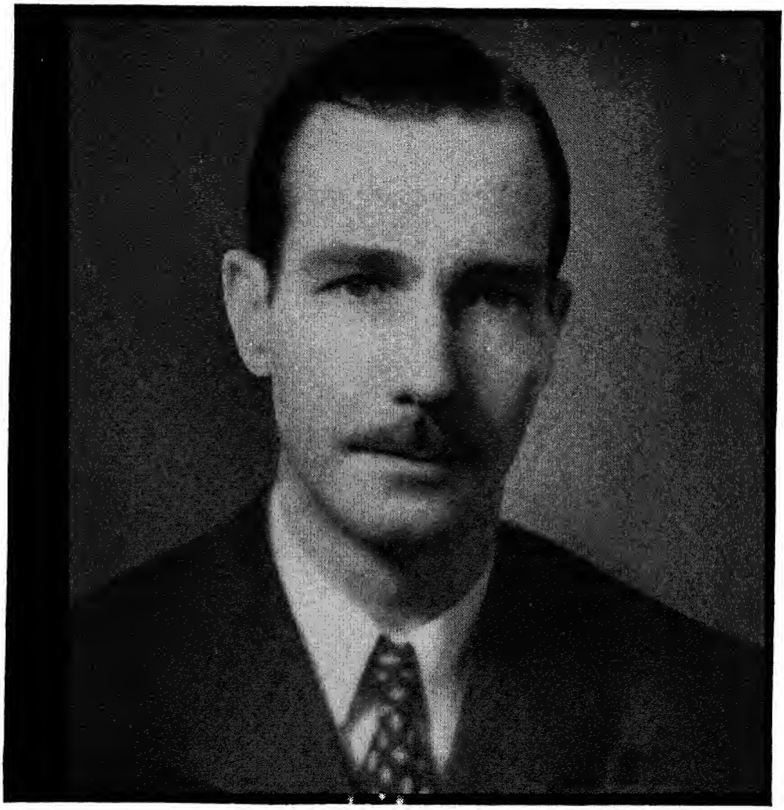
The Theater of the Stars

First of a Series of Three Talks Heard by Guests of the Forum Who Visited Buhl Planetarium

BY

ARTHUR L. DRAPER

Director, Buhl Planetarium and Institute of Popular Science



ARTHUR L. DRAPER, *Director*, Buhl Planetarium. Recognized as one of the outstanding planetarium lecturers in the country, he went to Pittsburgh in 1940 from the staff of Hayden Planetarium in New York. Educated at Cornell and Columbia universities, majoring in astronomy. For a number of years he broadcast popular-science programs and is author or coauthor of three volumes on astronomy.

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The Theater of the Stars

THE PROJECTION PLANETARIUM—THE AMAZING DUMB-bell-shaped optical instrument that has become familiar to millions of Americans in the last few years—is beyond doubt one of the finest and most versatile devices for the exposition and teaching of science ever developed. Before its invention, many of the fundamental concepts of the heavens were extremely difficult for the layman, for the nonastronomer, to comprehend. Now, with the projection planetarium and supplementary apparatus used in conjunction with it, these astronomical concepts can be grasped readily and quickly.

This modern glorified magic lantern is thus not only impressive in its uncanny ability to reproduce faithfully inside a building the appearance of the sky by day or night, creating an illusion that is truly startling and breath-taking in its beauty, but is equally remarkable as an instrument of instruction, presenting visually a multitude of basic facts in the science of astronomy and the related science of celestial navigation.

Experience has proved that such a place as this Theater of the Stars, with the newest of this country's five major projection planetariums, is ideal for teaching the groundwork of either science.

Why this is so becomes obvious from a résumé of some of the things that can be shown here, from meteors to galaxies, and some of the things that can be done, from

traveling in a few minutes all the way around the earth to traveling into the future and seeing stars and planets as they are destined to appear hundreds or thousands of years hence.

But first, what briefly is the construction of the projection planetarium, the essential element in the Theater of the Stars? The principle of its operation is the same as that of the old-fashioned magic lantern or stereopticon, which years ago used to project the pictures of postcards, perhaps scenes from foreign lands, upon the wall of a darkened room. In this case the pictures are those of the heavenly bodies, the small images of stars, the larger images of planets, moon, and sun.

The screen is the theater's great hemispherical ceiling, a curving shell of stainless steel painted white on the inside and fringed along the horizon with Pittsburgh's skyline of hills and buildings. When the theater is darkened and the stars appear, every star can be found in its proper place—all that can ever be seen by the keenest eye on the clearest night—a total of about 9,000 stars. The audience forgets it is in a room, for the man-made firmament above seems to have the immensity and endless sweep of the real heavens.

Actually, the projection planetarium is composed of over a hundred small, separate projectors which are matched and fitted together with exquisite accuracy. Thirty-two of these—sixteen in each ball of the "dumbbell"—project the images of the stars. In between these are other projectors for sun, moon, and planets, mounted so that each moves individually at the proper relative speed. The entire machine, however, is mounted in such a way that it can turn as a unit on any one of several axes.

For example, as it slowly spins on one axis, the star images move with it to reproduce the westward turning of the sky during the night, the setting of stars in the west, the rising of other stars in the east to take their place. With this motion a day and a night can be made to pass in 12 minutes, or 24 hours can be compressed into three minutes.

Similarly, various speeds are provided for the motions of the planets, sun, and moon, for a year can be made to go by in three minutes, one minute, or seven seconds. And so accurately geared are the projectors that it is possible to run ahead centuries into the future or back centuries into the past and find the planets, sun, and moon in their correct positions among the stars.

Another important motion of the whole machine is that which changes the latitude of the observer, so that we can have above us the skies as they would be seen from any spot on the earth from pole to pole. It is a simple matter to choose the spot you are viewing the heavens from, the date, and the hour of the day or night. These motions are all controlled by the lecturer by means of switches installed in the console at which he stands.

The controls are numerous and complicated. At will he can fade the stars and brighten the sky to produce a dawn, or jump instantly from the night sky to daytime sky, or put the projector through its paces in a hundred different ways. The lecturer's small optical pointer, which throws into the sky the image of an arrow, is invaluable in identifying stars and constellations.

Another great aid at his command is a series of projectors that add to the planetarium sky the imaginary reference lines of the astronomer, such as the meridian, the ecliptic, and the celestial equator. No longer imaginary

but now clearly visible, these lines and their meaning become easy for the beginning student of astronomy to understand.

Mention should be made of two unique features in this Theater of the Stars. One is a small disappearing stage, used on appropriate occasions for short dramatic episodes as part of the "sky show." When employed, it is not seen as the audience enters the theater. At the proper point in the progress of the show, the touch of a button slides back a section of the wall, and the stage—with actors and scenery already in place—moves out into the theater to be revealed only when spotlights are turned upon it. For part of the audience a clear view of the stage would be impossible, because of the projection planetarium being in the way, if it were not for the other unique feature—the elevator that Westinghouse engineers designed for the giant projector. At the touch of a button at the console the projector descends on the elevator into a shaft, to be brought up again when desired.

In a word, the outstanding reasons why the Theater of the Stars is unsurpassed for learning astronomy are these: first, one is never bothered by clouds or haze, since every night is crystal-clear; and second, a long astronomical action that takes place in the real heavens over some hours or months or years can be telescoped into minutes or seconds. Motions of the real sky too slow to be visualized except with much difficulty can be seen in the theater at a glance. In explanation of celestial phenomena, pictures largely take the place of words.

Let us look now a little more in detail at some of the possibilities of the theater. Consider the ease with which we can journey under the stars to any point on the globe we wish and a few of the things we see. Journeying north

from Pittsburgh at a speed of 5,000 miles a minute (fast enough so that we could circumnavigate the globe in five minutes), we find the heavens rolling overhead from north to south and swiftly we arrive at the North Pole. Stopping at the North Pole a bit, we discover our old friend the North Star directly overhead, still the pivot for the turning of the sky. As 24 hours go quickly by, we watch the stars moving in a strangely different fashion from what we were used to at home. They move now in circles parallel to the horizon, remaining always at a constant altitude. Here, as we see, no stars ever set; no others ever rise into view. Or, watching here a year's motion of the sun, we see how for six consecutive months it is above the horizon, giving the long polar day, and how for the other six it is always out of sight.

Then we journey to the earth's equator, where we find a different situation still. Here the stars and sun rise always straight up and set straight down—perpendicularly to the horizon. And the day, we find, is always 12 hours long throughout the year, with 12 hours left for the night.

Leaving the equator and continuing on to the South Pole, we find conditions comparable to those at the North Pole, although the North Star is never to be seen, nor are many of the stars familiar to us in the northern hemisphere. In their stead shine the stars of the Southern Cross and Alpha Centauri, nearest known star (about 25 trillion miles distant), and the beautiful clouds of stars known as the Clouds of Magellan. We return to Pittsburgh, and our watches tell us that only a few minutes have passed.

The speeded-up motions of the sun, moon, and planets show us with equal facility many interesting things. The manner in which the phase of the moon changes becomes

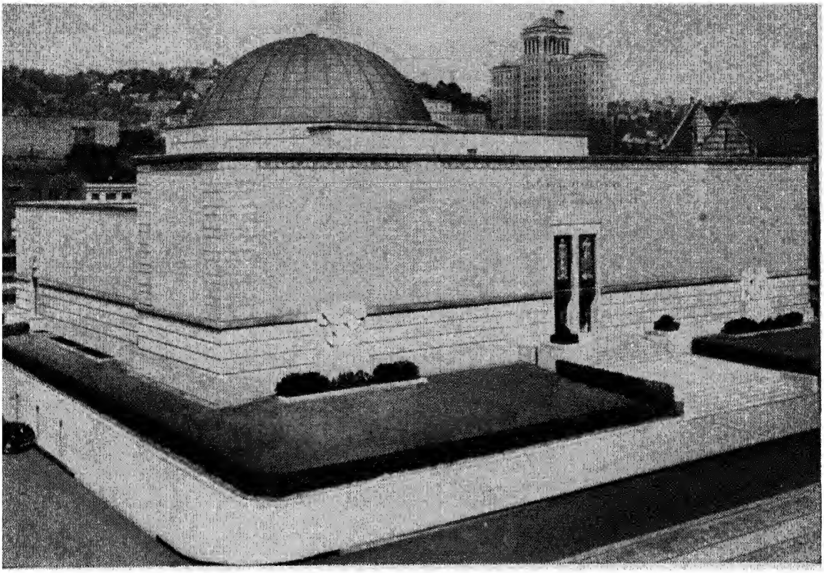
clear, as the waxing crescent of the new moon leads to the first quarter moon and this to full and on through the lunar cycle.

As the sun pursues its course through the year, we can get in a few moments a clear mental picture of the changing phenomena of the heavens connecting with the seasons. It becomes evident why the sun attains a high position at noon in summer, why its height is average in spring and fall, and lowest for the year in winter. Living a whole winter's day in a matter of seconds, we see how the short path of the sun across the sky results in a short period of daylight, and how the reverse is true in summer. Then, too, the curious and varying behavior of the planets is visualized without trouble with time accelerated, as they follow their individual paths around the celestial sphere against the background of the constellations.

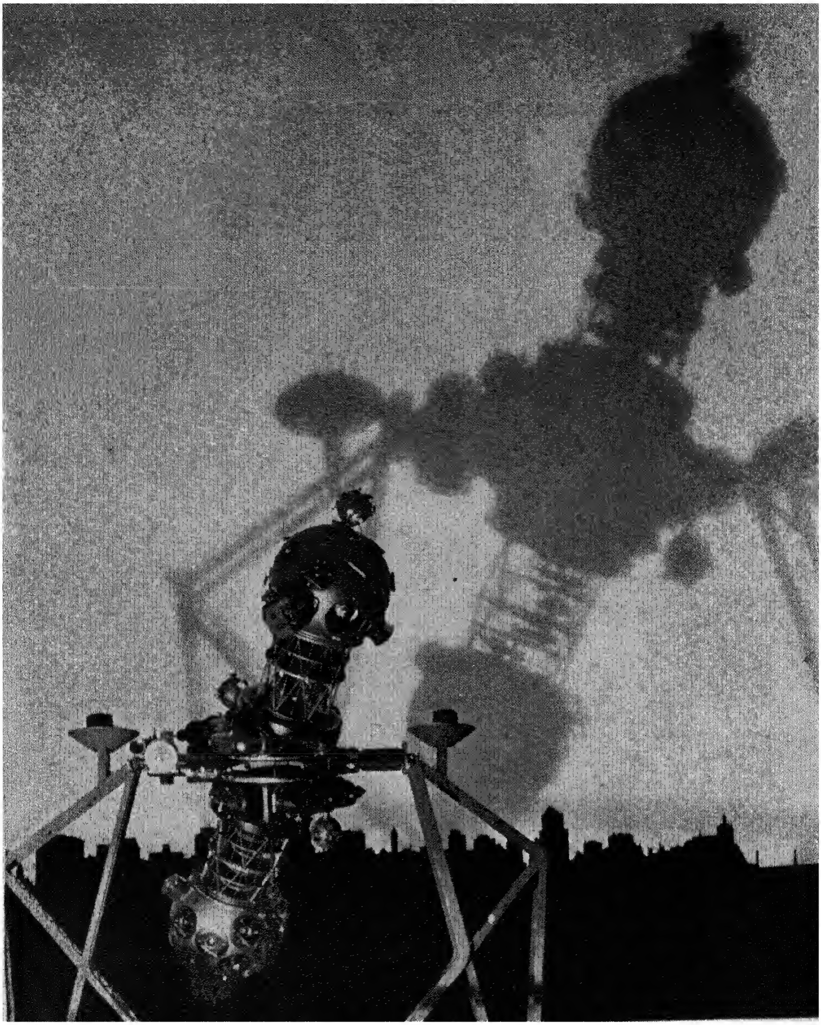
We can observe Mercury and Venus, the two planets closer to the sun than is the earth, shuttling regularly from one side of the sun to the other, never getting very far from it in either direction. But we observe the other three naked-eye planets—Mars, Jupiter, and Saturn—moving at differing speeds completely around the sphere of the sky relative to the sun, so that at times they are opposite the sun, or in "opposition," to use the astronomer's term.

Now it must be remembered that, in the planetarium sky, the planet's motions are reproduced as they are seen from the earth. It must be remembered as well that their apparent motions as seen from the earth are the result of their own real motions about the central sun combined with the motion of the earth—which, itself a planet circling the sun, provides us with a constantly moving place of observation.

For that reason, as a complement to the projection



The Buhl Planetarium and Institute of Popular Science, Pittsburgh, Pa.



Star projector in the Buhl Planetarium Theater of the Stars.

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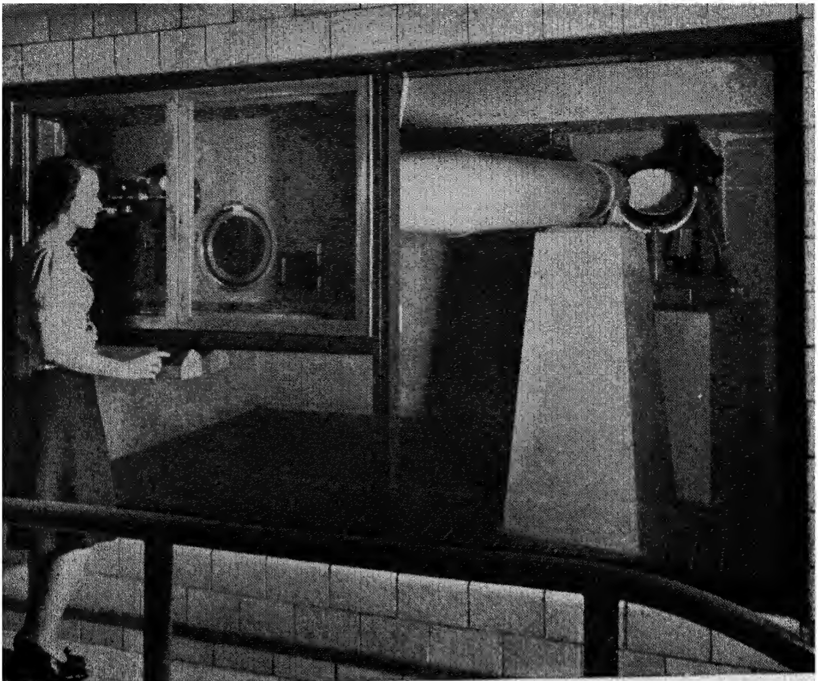
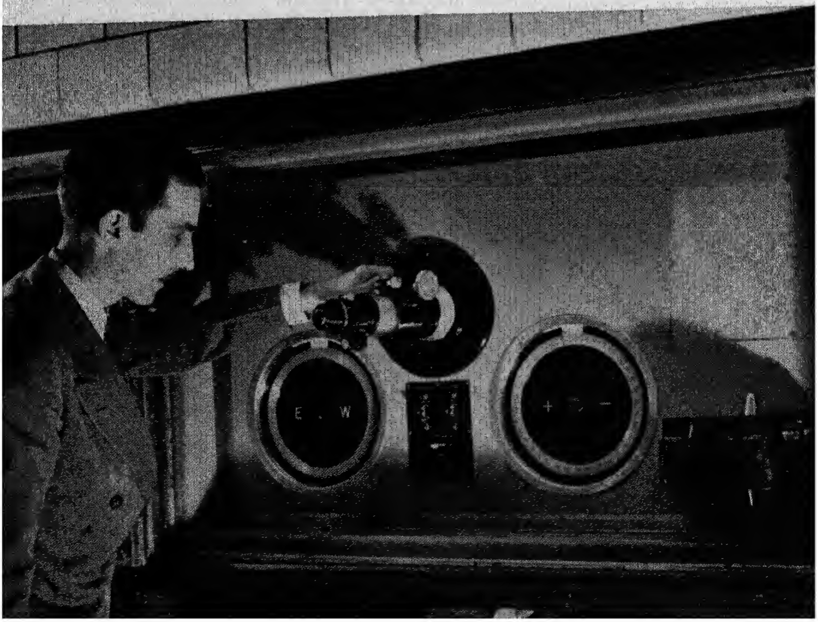
The projector reproduces a star-studded sky.



Siderostat telescope, showing eyepiece telescope tube and siderostat mirror.



A close-up view showing the eyepiece of the siderostat telescope.

planetarium, another sort of "planetarium" is a most helpful adjunct in understanding the planetary motions. This is the much older type of planetarium, which is often called an "orrery"—really a three-dimensional model of the solar system. Such a model is to be found in one of our exhibit galleries, and in this case as the visitor watches the planets moving in their respective orbits about the sun he is observing from a new point of view.

He is looking in at the earth and the rest of the solar system from the outside and is aided in gaining a conception of the true motions of the planets in space. The satellites, or moons, of the various planets are also seen circling their primaries. Such a model presents some of the evidence that has convinced the modern astronomer that the planets had a common origin, that the earth and the others began in the same way and at the same time—probably about 2 or 3 billion years ago.

Returning to the Theater of the Stars, I should mention that the projection planetarium is equipped to reproduce the motion, as seen from the earth, of another type of body which is part of the solar system—the comet. It is possible to see speeded up the stately course of a brilliant comet over a period of several months, as it follows its extremely elliptical orbit in space around the sun.

It is frequently desirable in the theater to install small projectors and other "gadgets" to supplement the work of the dumbbell and increase the flexibility of its use. These sometimes temporary installations are specially designed and built to create special effects in the planetarium sky. To suggest what can be done in this way, let me enumerate a few of the special sky effects that we have produced. The lecturer slowly turns a rheostat, and visitors discover one of the stars gradually brightening until

it becomes the most brilliant object in the heavens—the nova or so-called "new star." He pushes a switch and a cosmic-ray counter begins to operate, recording the arrival from outer space of the mysterious cosmic rays that some believe may originate in the novae; these are the real thing, of course—rays that have actually penetrated the roof of the planetarium building in ending their celestial travels. With other rheostats the constellation pictures can be faded in among the proper stars: the quaint figures of animals and heroes imagined in olden times by the Greeks and Romans. We can add to the sky a beautiful arching rainbow or the lunar halo—the "ring around the moon"—or the many-hued streamers and arcs and curtains of the aurora borealis, the northern lights.

We can have colorful sunsets and realistic dawns, eclipses of the sun and moon, and various cloud formations useful in predicting weather. We can reproduce a violent thunderstorm, complete with sound effects of rain and thunder. The entire planetarium dome can be converted instantly into a hemispherical map of the earth, useful in teaching navigation. We can produce all the necessary visual effects for an imaginary rocket journey to the moon. Arriving there we see a mountainous lunar horizon, in complete detail and in color, and in the lunar sky the spinning globe of the earth, distant now 240,000 miles.

Magically, the huge globe of the planet Saturn appears, seen as though through a powerful telescope and showing the slow tilting of its strange ring system. Similarly the globe of the sun can be seen as though telescopically, with the sunspots—vast solar cyclones—visibly moving around with the rest of the sun as that body spins like a massive top.

No reproduction of that kind, however, can take the place completely of a real telescope, by means of which the real sun and the other heavenly bodies can be observed when weather permits. We have such an instrument in our roof-top observatory and this, like the orrery, supplements importantly what visitors see in the theater. The planetarium's siderostat telescope is believed to be the only one in the world especially built for observing celestial objects by the general public. The siderostat telescope never points toward the sky. Instead, it points at a mirror which does the work of "star catching." This mirror does the moving, catching the light of a star and reflecting it into the telescope—bending starlight around a corner, so to speak. With ordinary telescopes, the observer must twist his neck to look into the eyepiece. More, he must move his body to follow the telescope's movements as it follows the star or planet across the sky.

The observer at our telescope stands or sits in a normal position and looks through the always-horizontal apparatus. The mirror does all necessary adjusting. Also, there is no discomfort from cold. In the regular observatory the observer must be in a room that has the same temperature as the outside air. But our observatory has two rooms, with the objective lens and mirror in the room open to the night air, and the eyepiece in a room kept at a comfortable temperature. A glass partition separates the two rooms, so that visitors may see the machinery in motion.

There is still another possibility of the projection planetarium that is worthy of mention, its ability to reproduce the slow precessional "wobble" of the earth's axis, which in reality completes one cycle in a period of approximately 26,000 years. This wobbling of our planet is similar to that of a top that is slowing down and has the

effect in the sky of making different stars in turn the "north star" in successive eras.

In the theater, the 26,000 years are condensed into a trifle over a minute, so it is not difficult to be transported back into the past a few thousand years, to see the star Thuban occupying the place now held by our "north star," or to jump ahead into the remote future, to see the brilliant star Vega attaining that position.

An educator's dream come true—that is the Theater of the Stars. At the lecturer's behest the grand and awesome pageant of the heavens is reenacted. The audience can one moment watch the graceful flashing of the meteors that pelt our planet and burn up as "shooting stars"—the nearest heavenly bodies we ever see. The next moment it can gaze upon the misty haze of light which is the Great Nebula in Andromeda—the most distant object visible to the unaided eye, a galaxy so distant that its light requires some 700,000 years to travel through the emptiness of space to this earth of ours.

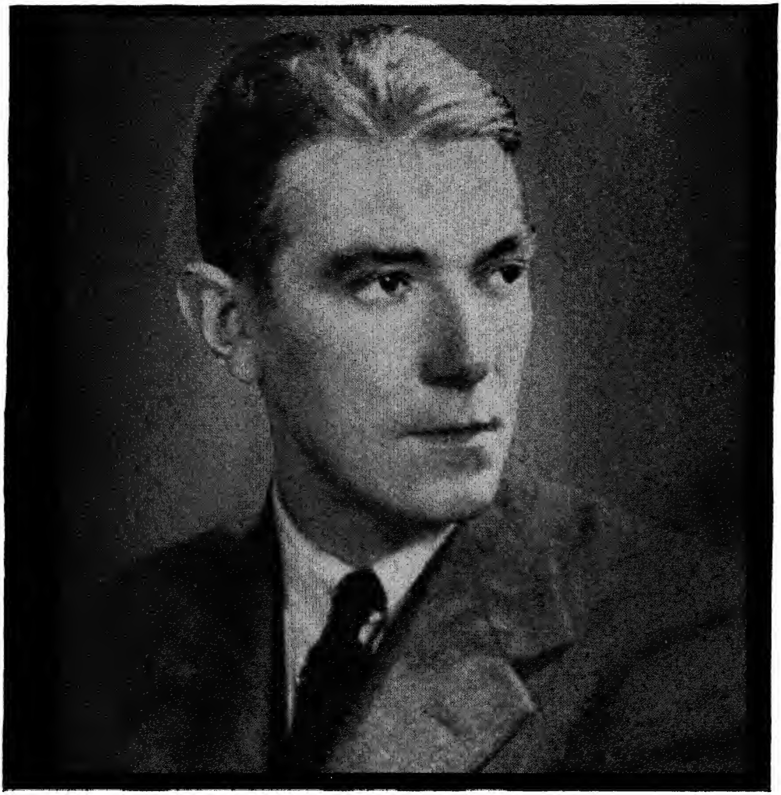
To the man in the street, the Theater of the Stars is a thing of beauty, bringing him in a little space some of the immensities of the universe. To the teacher of astronomy it is truly a joy forever, since in science education its possibilities are almost endless in bringing the heavens down to earth.

The Micro-zoo

BY

DR. PETER GRAY

Acting Head, Department of Biology,
University of Pittsburgh



DR. PETER GRAY, *Professor of biological sciences, Acting Head,* Department of Biology, University of Pittsburgh, member of Buhl Planetarium staff. Imperial College diplomate; has doctorate from University of London; was faculty member at Edinburgh University. Recognized for research in field of chemical embryology; consultant in tropical problems to industry and the armed services.

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The Micro-zoo

The following is a summary of Dr. Gray's lecture—delivered before guests of the Forum—demonstrating the use of optical facilities of the Buhl Planetarium and Institute of Popular Science as teaching aids in the biological sciences.

IT SEEMS LOGICAL THAT THE TEACHING OF ANY SUBJECT should be bound to a philosophical basis, and it is evident today that the most commonly employed philosophical framework of the teaching biologist is the concept of evolution. In the majority of cases, however, this concept is very difficult to use for the reason that the dry bones of the subject are very literally used in the place of the living material.

The relationship between one organ and another, although it may be very apparent to an experienced biologist, is not apparent to a junior and inexperienced student unless function rather than anatomy is used as a basis. And this function is undoubtedly better observed in a living animal than it can be explained—no matter how realistically—with the corpse of a dead one.

The two instruments that seem to adapt themselves best in the teaching of biological sciences are the micro-projector and the epidiascope, both of which I have here today in the highest stage of their development. First, it is necessary to issue a word of warning about the concept of magnification. It would convey little to high-school seniors, who are my usual audience here, were I to show

them an amoeba under a high power and expect them to retain the slightest concept of its actuality.

It is for this reason that I start with the lowest available magnification, which permits me to insert the tip of my little finger into the field and, while keeping the shadow of my finger on the screen, change to a power once higher, leaving nothing but a blurred edge visible. It is now possible for the student to have related the size of an amoeba to the size of the cover slip, and the size of the cover slip to the size of my little finger.

As I continue to pass to higher and higher powers this concept remains with the student, and the amoeba stands before him in its rightful place in the size scale. I do not think I need bore you with a description of the anatomy of this singularly uninteresting animal, but in case you have never seen it before, I do want to point out to you protoplasmic flow into these pseudopodia which you see growing out, and to draw your attention to the remarkable powers of selectivity that this form possesses. Were it possible for me to arrange a collision between an amoeba and Paramecium, the latter would be speedily trapped; yet when two amoebae come together they can glide past each other in even the narrowest capillary tube without either endeavoring to absorb the other.

Reverting to our evolutionary framework, it seems to me unfortunate that the amoeba should be placed so usually at the bottom, since I think it is nowadays becoming more and more apparent that it is a degenerate rather than a primitive form. It does, however, serve the admirable purpose of providing a point of departure toward the more complex form, Paramecium.

I find that it impresses my customary audience to point out that even here there is allied to movement the

beginnings of symmetry, in that, although the animal is perfectly capable of proceeding in either direction, it prefers usually to move with the blunt end forward, and that we may therefore apply the term "head" to this blunt end. It is very dangerous but extraordinarily attractive to endeavor to analyze the behavior of these actively moving forms in terms of human experience. You will notice that the Paramecium in the center has just solved a problem by a process which, were it to be used by a young human child, would be referred to as trial and error.

As these forms collide head on with the algal strands in the maze in which so many of them are lost, they reverse instantly and draw off; and when they return to the charge, they do so invariably after an angular displacement of from 10 to 15 degrees. A continuous series of trials therefore expands the degrees of the exploration to 360 degrees, so that, were there to be an exit from the trap in which they find themselves, they inevitably, and it is difficult not to say logically, discover it.

Although I am supposed to be giving a biological demonstration, I cannot resist introducing physics to the extent of this high-voltage ultraviolet discharge tube based on the Westinghouse "Sterilamp." I have here another slide of Paramecium, which has not only many animals under the cover slip, but also many animals swimming in the water that has escaped from its edge. When they are exposed to an ultraviolet discharge, those in the water are instantly killed, while those protected by even 1/100 inch of glass are either undamaged or, at the most, slightly bewildered.

It would be fascinating to show you a larger series of animals than the time permits, but I should like to take a brief excursion into the realms of sheer beauty by show-

ing you a slide of a living Stentor. I know of no more gracefully shaped or delicately colored animal in the realms of nature. Continuing with the main theme of increasing complexity by evolution, the anterior end of this form is now inexorably fixed as a "head," while in the "tail" specialized cells have developed for purposes of adhesion.

You are probably aware of the hypothesis of Hyman, that all these so-called "single-celled animals" are descendants of many-celled ancestors that have lost their cell walls. Indeed it must be emphasized that the number of Protozoa having a single nucleus can be counted on the fingers of both hands. In Stentor, further, there are fine strands of protoplasm, which not only are contractile, but exhibit the stain affinities of muscles of higher forms. Some surface fibrelli have nerve stain affinities, which we tend to identify as nervous in function.

I always find that there is a very easy transition from Stentor to the form Hydra, although there is biologically an enormous gap between them. It is so easy for students to identify the head and the mouth, and when they additionally see the form contract through muscle fibers in its walls it seems to them logical that the one should have been derived from the other. I do not suppose that anyone today would imagine such a derivation to have taken place, but it seems better to hold to this framework of a continuously increasing complexity of an evolutionary series until a better philosophical basis has been discovered. The Hydra, of course, is one of the few forms in which sections of the dead body can display the evolutionary changes better than can the living form, but its behavior forms a far better transition for the benefit of the uninstructed.

Transitional between the Hydra and the Arthropoda, which I am sure you must already have gathered to be looming over the horizon, are two other living forms, Stylaria and an insect larva.

I do not know why the worm Stylaria is not more commonly employed for class purposes. It has everything that a good model should display—the rings around the body, which introduce logically the subjects of metameric segmentation and division of labor; the increased specialization of the anterior end, permitting it to take a logical place in the sequence that we are building; a clearly defined alimentary canal, permitting us to take one step forward from the Hydra; and finally a habit of controlling its contractions so that, instead of the all-or-nothing reaction, it is possible to explain how the control of this contraction by a centralized nervous system permits the beginning of a well-directed locomotion.

A small larva of a fresh-water insect is so like the worm at first glance that even the most unintelligent student has no trouble correlating the one with the other. The mouth parts, moreover, are so clear that one can without the slightest difficulty continue on this theme of cephalization, at the same time drawing attention to the hardened and jointed outer covering, which one can introduce as a logical step toward the beginning of a terrestrial existence.

I have never felt, however, that this transition between the annelid and the arthropod permitted one to build up sufficiently strongly the case for joints, and I have always found it convenient to use an Anguillula as an example of what happens to a worm that clothes itself in an unjointed sheath. The aimless wriggling of a nematode worm cannot be regarded as a logical step forward in the path that we are building and permits us, therefore, not only to make

the point about the utility of the joints, but also to introduce the idea that every variation is not of necessity a step forward, but is merely a step. I usually leave these worms on the screen to hold the attention of the audience while I expound—to those who still believe man to be descended from the amoeba—the concept that evolution has proceeded along widely divergent lines, many of which terminate in living and apparently unrelated forms.

The complexity that can be reached by some of these forms is admirably illustrated by the invertebrate Simnocephalus, which is the cladoceran usually selected for demonstration under the name of "Daphnia."

Here can be seen in action almost every organ that the average high-school student presumes to be present in his own body. The alimentary canal shows the rhythmic peristaltic waves sweeping from front to back. The food, bright green in the anterior end, changes to a dull brown as it passes backwards. The digestive caecum from the anterior end of this canal can also be used to indicate the formation and the relationship of the liver. It is surprising how clearly the brain is shown; even the optic nerves stand out plainly in this remarkable specimen. Then, too, there is the rapidly beating heart, the first heart that many people have ever seen in action.

Unfortunately, the short time at my disposal today does not permit me to dissect a vertebrate and display its anatomy. Surveys have shown clearly that a dissection that can be watched on the screen, where the hands of the operator bring into view organ after organ, leaves an even better knowledge of anatomy in the eyes of the onlooker than would be obtained in a dissection of their own specimen. However, there is one thing that I should like to do with this other machine—one of the best

epidiascopes in the country—which bears directly on the beating heart on the other screen. I can try to convince you—for if you are not biologists you will require convincing—that there is no animal in the world that can develop save under the surface of water. This oval object is not an egg as that term should properly be used. It is an egg pumped full of yolk so that the terms are confused together, and round which the parent bird has most cunningly wrapped a pond before enclosing the whole in a protective shell. It was this brilliant discovery of the birds that the pond could be taken to their nests, rather than their nests taken to the water, which first made the so-called "conquest of the land" possible to the backboned animals.

I have here a finger bowl of slightly salted water, into which I am going to break this egg, which has been incubated for two days. As I withdraw the halves of the shell it is quite clearly shown, even with this low magnification, that the red blood vessels spread further over the yolk to aid in its absorption. You will appreciate that this form is now living under the surface of an enlarged pond to which I have transferred it from its shell. By clipping rapidly around the edges with scissors I can separate a thin membrane-like material in which the whitish outline of the embryo can be seen indistinctly.

By sliding a slip of glass under this embryo, I can withdraw it for the first time in its life from the fluid that is its natural habitat, and substitute it for the specimen under the microprojector. Now we can see the beating heart of what we would almost call a fish had we not seen it come from the egg of a bird. It is even possible at this point to see that clear whitish slit, which is in effect a gill slit, and a direct adaptation, in the blood vessels it contains, to life under the surface of fluid.

Thus we attempt to build in the mind of a high-school student some picture of the animal kingdom, based on a framework of evolutionary philosophy, adopting as the main steps of this argument: first, the production of a head; second, the production of a jointed skeleton; and third, the idea that all these processes had not come to a stop, so that even our close relatives, the birds, were still linked directly to the ancestorial fish type.

Symmetry in Nature

BY

DR. E. K. WALLACE

Professor of Chemistry, Pennsylvania College for Women

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Symmetry in Nature

A layman's introduction to crystallography and the use of microprojection with polarized light, presented by Dr. Wallace to Westinghouse Centennial Forum guests at the Buhl Planetarium and Institute of Popular Science.

THE ORDERLINESS OF NATURE IS EVIDENT AT ALL TIMES in the solids in and on the earth. A casual glance at soil or rock does not reveal order or beauty. All matter appears to be lacking definiteness in shape and, erroneously, is classed as amorphous. Quite the opposite is true. The natural solid compounds are largely crystallized. To mention the word "crystal," thoughts are immediately drawn to the gems and perhaps to the king of gems, the diamond. Quite incorrectly the imagination of the reflecting surfaces of the diamond leads one to think that naturally the diamond has many flat surfaces, planes, bounded by sharp edges. In actuality the diamond (Figs. 1 and 2) is a modified octahedron with slightly curved surfaces.

Nature generally provides that all specimens of the same solid have the same shape. However, this is not always the case. Another crystalline form of carbon, besides the diamond, is graphite. The graphite has a different crystalline structure from its allotropic form, the diamond. The common cousin of the diamond, coal, lacks definiteness in physical structure or is classed as an amorphous solid.

Even though gems are not necessarily the primary interest when crystals are studied, some gems are always appealing because they possess crystalline splendor. A list of several gems and their structures is: aquamarine, hexagonal; beryl, hexagonal; chrysoberyl, orthorhombic; emerald, hexagonal; garnet, cubic; ruby, hexagonal; sapphire, hexagonal; spinel, cubic; topaz, orthorhombic.

What is meant by terms such as hexagonal? They are man's method of designating a class of geometric solids to which nature has assigned the various gems and other solids.

We are often reminded that crystals take on innumerable forms. This need discourage no one in an effort to arrange all the multitudinous forms. Nature in all its complexity follows simplicity and symmetry as a pattern. There are only six classes of crystal structure, ranging from the most symmetrical to the least.

Everyone is acquainted with a cube, a solid figure of six sides, each of which is a square. This is exemplified in common salt crystals. What is the extent of its symmetry? If through the centers of two of the opposite sides of the cube an imaginary line is drawn and the cube rotated on this line as an axis, the four other sides will take similar positions in succession. The positions are said to be symmetrical.

To describe completely the symmetry of the cube, two more imaginary axes—joining the mid-points of the two remaining sets of parallel opposite sides—need to be constructed. The positions of the three axes relative to each other, as well as their respective lengths, need to be considered. It will be found that the three axes of symmetry of the cube are all perpendicular to each other and all three have equal lengths.

FIG. 1. Diamond crystal, 442 Carats, found 1917. Reported to be the most valuable stone found in the mines at Kimberley, South Africa. (*DeBeers Consolidated Mines, Limited.*)

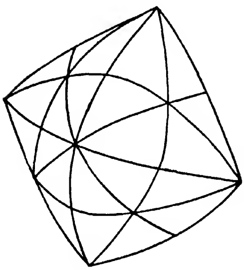


FIG. 2. Crystal form of diamond.

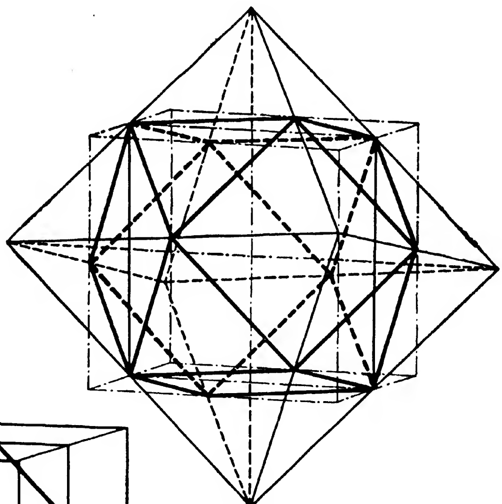


FIG. 3. Octahedron cut by cube.

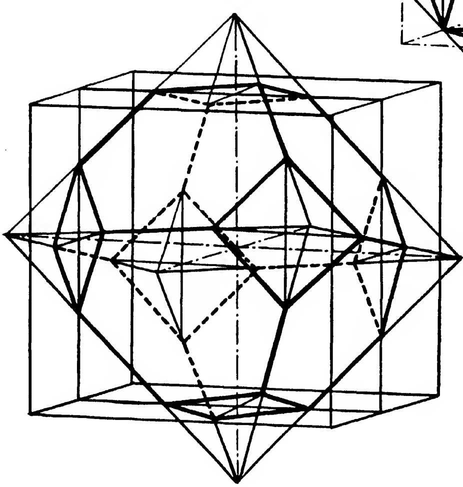


FIG. 4. Cube cut by octahedron.

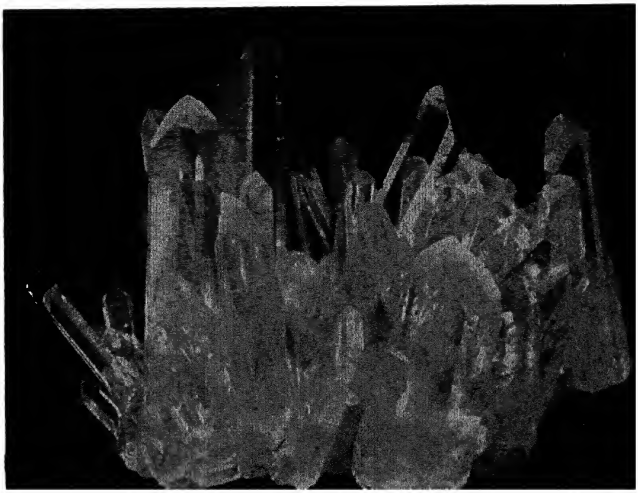


Fig. 5. Attached crystals of quartz, near Hot Springs, Arkansas.

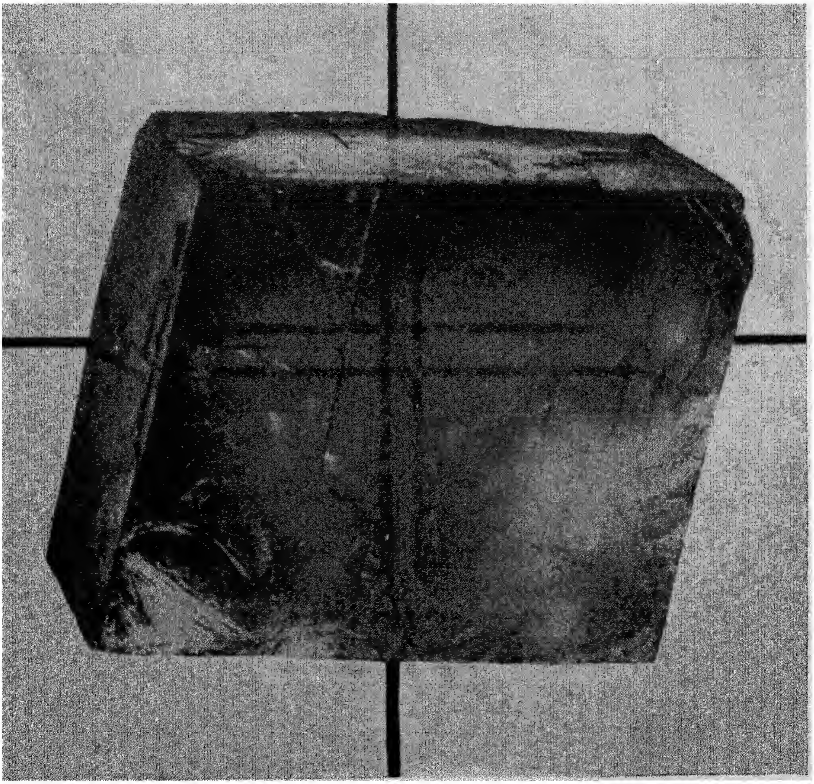


Fig. 6 Double refraction of light by Iceland spar. (*Museum of Brooklyn Institute.*)

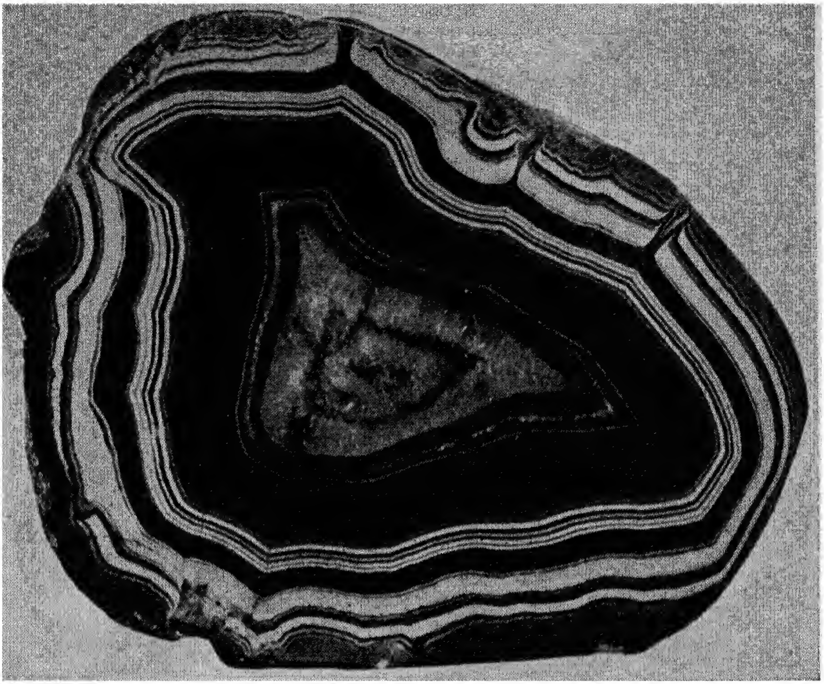


FIG. 7. Agate showing concentric structure, Brazil.

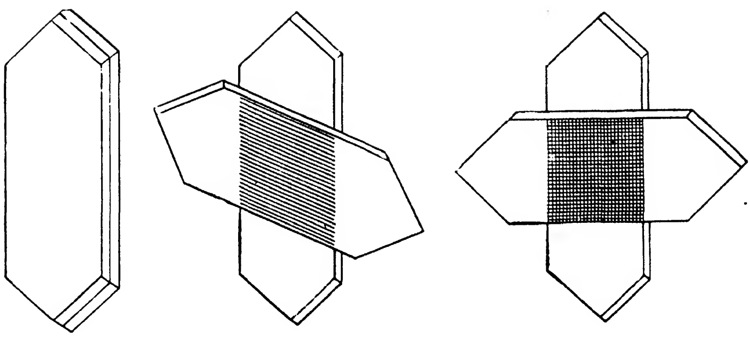


FIG. 9.

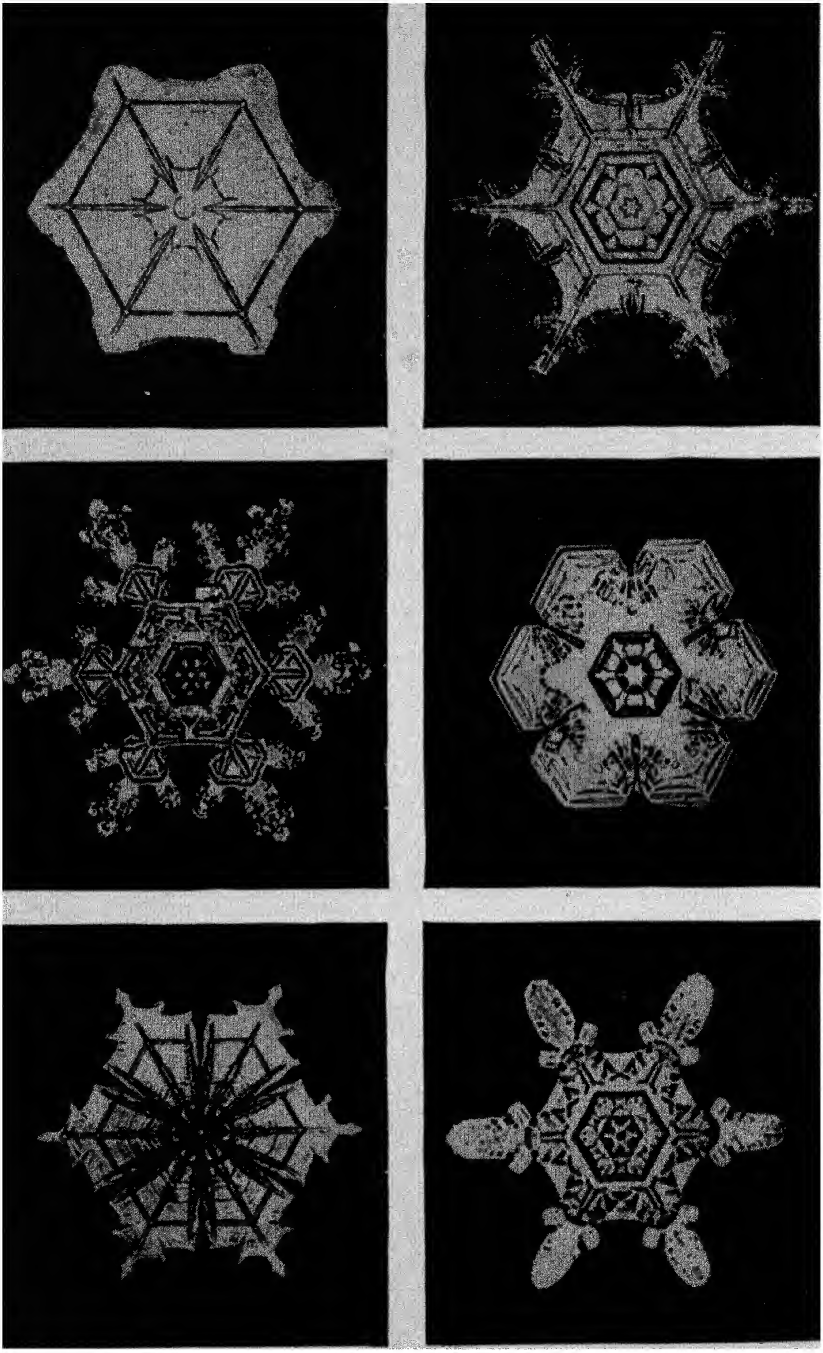


Fig. 8. Microphotographs of snow crystals. (*W. A. Bentley.*)

Thus the cube belongs to a class of crystals having three axes of symmetry mutually perpendicular and equal. Any solid geometric form possessing these characteristics belongs to this class. Likewise the octahedron is a member of this class, the cubic or isometric system.

The cube and octahedron are typical figures representing the prismatic and pyramidal forms, which are subclasses of all crystallographic systems.

The systems may be differentiated in this manner, where A, B, C, D are axes of symmetry.

System		*Axes*
Cubic or isometric....	$A = B = C$	All perpendicular.
Tetragonal...........	$A = B \neq C$	All perpendicular.
Orthorhombic........	$A \neq B \neq C$	All perpendicular.
Hexagonal...........	$A = B = C$	All in the same plane making 60-degree angles with each other, and all three are perpendicular to D, but not necessarily equal to D. Four axes intersect at common point.
Monoclinic...........	$A \neq B \neq C$	A is perpendicular to B only.
Triclinic.............	$A \neq B \neq C$	No two axes are perpendicular.

Examples of the systems are: cubic, rock salt; tetragonal, potassium dihydrogen phosphate; orthorhombic, potassium nitrate; hexagonal, sodium nitrate; monoclinic, barium chloride dihydrate; triclinic, potassium dichromate.

Does nature cause crystals to form by combining characteristics of several systems? Again the way of nature is simple in that only crystals are formed as modifications of the same system (Figs. 3 and 4).

The natural crystals have been formed either from solution or from a molten mass.

When crystals are formed from solution, as in the case of salt in a mine, the solvent water evaporates. When the solution becomes saturated, any additional removal of solvent causes solid to separate. The crystals at first are small, but if the evaporation is slow the crystals increase in size. If the evaporation is rapid the crystals formed will remain small. If any of the above examples of salts (representing the various systems) are crystallized in the laboratory, beautiful large crystals are formed only on very slow evaporation. When evaporation takes place in a shallow surface and the crystals are not surrounded by the saturated solution, the growth will be along the flat surface. The crystals, growing into each other, are distorted and of varying depth.

Many of nature's beautiful gems have their origin in a molten magma. When the crystals are unhampered while forming, they will form beautiful specimens, as shown in Fig. 5, a photograph of quartz.

A similar example is Iceland spar (Fig. 6).

When a mixture of substances in the molten state starts to freeze, as in the case of a geode, the agate (Fig. 7) is formed.

The various components do not freeze simultaneously, but each freezes separately, and the various layers are deposited in irregular rings starting on the outside and continuing into the center. The central portion in this case is quartz. Since the quartz crystals have no room in which to grow, they are distorted.

It is very seldom that the formation of snowflakes is recognized as crystallization of a fused mass, water. The pictures of snowflakes (Fig. 9) again illustrate nature's

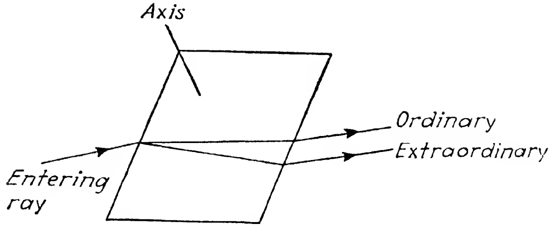


Fig. 10. Birefringence.

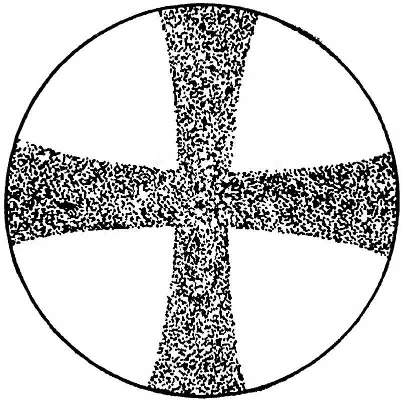


Fig. 11. Interference—uniaxial.

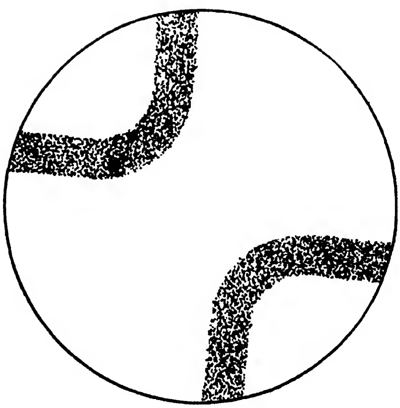


Fig. 12. Interference—biaxial.

regularity in always forming crystals of the same substance in the same crystalline system—in this case, hexagonal.

In order to study crystals while in the process of formation or in small quantities, they are formed on slides and these slides are examined under the microscope.

The growth on the slide may be followed, as previously stated, from a saturated solution. The solvents used are water, ethanol, benzene, petroleum ether, and acetone. The low-boiling solvents are preferable. Some substances, such as sodium acetate, form supersaturated solutions. These may be inoculated with small crystals of the same substance or merely scratched with a sharp object to start growth.

Other substances, like thymol and urea, are fused on the slide and allowed to cool to cause crystallization to take place.

Still other substances, like benzoic acid, will sublime, and resublimed crystals are observed.

Many crystals are colorless and transparent. The naked eye misses much of the beauty of colors of the spectrum ranging from the violet to the red rays when the light rays of various wave lengths pass through the crystals. The eye, when aided by polarized light and the magnification of the microscope, is treated to some of the most fascinating displays of colors and designs, well beyond the imaginative description.

The polarization of light can be accomplished with a naturally crystalline substance, tourmaline. When the transverse waves of light strike the parallel striations of the tourmaline, only those passing in the direction of the striation planes will pass through and form plane-polarized light. If two very thin sections of tourmaline are placed

so as to have their striation planes parallel, the rays of plane-polarized light passing through the first will also pass through the second.

If, however, the tourmaline sections are gradually rotated until they are finally perpendicular, the light passing through the first section will not pass through the second, and (Fig. 8) no light will then pass through that area of the tourmaline lenses that overlaps. In other words the area will appear dark.

The same effect can be produced with greater efficiency by the use of polaroid disks. These polaroid sheets are connected directly to the microscope. One is below the slide to be examined and the other above the eyepiece. In order that a number of persons may observe the image, the light coming through the eyepiece of the microscope is reflected, magnified, and projected on a screen. A suitable magnification is 300 times.

Some crystalline substances have the property of optical rotation (rotating the plane of polarized light in its course while passing through them). Such a substance is a tartrate that Pasteur first studied in connection with the residues in wine casks. When placed under the microscope with polaroid disks, the field will remain light even though the disks have their striation surfaces perpendicular to each other. If one of the disks is turned, the field will eventually be dark and the angle of rotation can be measured.

Quite different from the property of optical rotation is the property of birefringence, or double refraction. In the photograph of Iceland spar (Fig. 6), two perpendicular lines were drawn on the paper that serves as a background for the crystal. It will be noticed that the lines as viewed through the crystal appear as double lines. Normally light

Fig. 13. Polaroids with axes parallel.

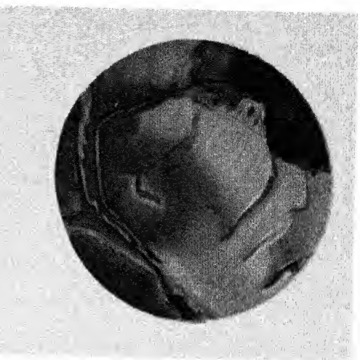


Fig. 14. Polaroids with axes perpendicular.

when passing from one medium is bent in its course (refracted) when passing through the second medium. In the case of Iceland spar (calcite) there are two refracted rays instead of one, as illustrated in Fig. 10.

If the crystal of calcite were turned and inclined, light passing through it in one certain position would be refracted in only one direction. This is true when the light waves travel in the crystal in the direction of its optic axis.

It is not to be inferred that all crystals exhibit birefringence. Those which do are called "anisotropic," while those which do not are called "isotropic."

Some crystals, which have one optic axis, are called "uniaxial," while others, which have two optic axes, are called "biaxial."

The isotropic or anisotropic properties depend upon the crystallographic system to which the substance belongs, such as: cubic, isotropic; tetragonal, uniaxial; orthorhombic, biaxial; hexagonal, uniaxial; monoclinic, biaxial; triclinic, biaxial.

Another optical evidence, the appearance of an interference figure, is possible in crystals that are uniaxial and biaxial.

In the case of a uniaxial crystal, a beam of polarized light may be passed through it so that the direction of the optic axis is perpendicular to the plane of the section. If the emergent ray is examined in such a way as to extinguish the original plane-polarized beam, a circular object with a dark cross will be seen (Fig. 11).

If the polaroids are placed so as to have parallel optic axes, the dark part becomes light, and vice versa.

In the case of a biaxial crystal, the interference figure is as shown in Fig. 12.

Still another phenomenon is in evidence when only one

polaroid is used with colored anisotropic crystals. Depending upon the position of the crystal, certain light waves will be absorbed. In other words, the light emitted will be of different colors, depending upon the direction of the crystal. This property, pleochroism, is typical of substances such as silver chromate, copper sulphate, and Congo red. Pleochroism becomes dichroism when only two colors are emitted when the crystal is in various positions.

When strong white light, such as that furnished by a carbon arc, is passed through growing crystals under polarized light, the properties of birefringence, interference, and pleochroism become evident. Also, as previously mentioned, the crystals are growing in close proximity with various crystals present in different positions. All this presents beauty and variation of structure as is shown only by the two colored photographs (Figs. 13 and 14), one with the polaroids with parallel optic axes and the other with the polaroid axes perpendicular to each other.

Substances other than those mentioned above which produce extravagant splendor of color are silver nitrate, pyrocatechin, potassium chlorate, ammonium oxalate, sodium thiosulphate, elon, acetyl-salicylic acid, monochloracetic acid, asparagine, tartaric acid, and microsections of mica and quartz.

Further experimentation, if desired, can be conducted by precipitating substances, such as silver nitrate with potassium chromate, under the microscope.

Also a spectacular scene is produced in the form of a lead tree by placing a zinc sheet, with a circular section removed, on the microscope slide and adding a dilute solution of lead acetate.

A Trip through Mellon Institute

An Address Heard by Forum Guests Who Visited the Institute

BY

DR. EDWARD R. WEIDLEIN

Director, Mellon Institute

Dr. Edward R. Weidlein, *Director*, Mellon Institute. Scientist, inventor, and author, connected with institute for 34 years, director since 1921. Had many important wartime duties, including membership on Research Committee, Chemical Warfare Service, American Chemical Society; and Committee on Cooperation with Office of Scientific Research and Development. Chief of Chemicals Branch of War Production Board, adviser for Rubber Reserve Company and Quartermaster Corps. Awarded numerous medals. Author, with Dr. William A. Hamor, of *Science in Action* and *Glances at Industrial Research*. Honorary member of Chemical, Metallurgical and Mining Society of South Africa and Institution of Chemical Engineers of Great Britain. Past president of American Chemical Society and Institute of Chemical Engineers.

A Trip through Mellon Institute

MANY YEARS OF PLANNING AND SIX YEARS OF ACTUAL construction reached their culmination as the new home of Mellon Institute was dedicated on May 6, 1937. In the 36 years since the inception of the institution it has outgrown two previous structures, because of steady expansion of its work for the benefit of humanity through scientific research. Now it is able to carry on all its present investigations with greater effectiveness and scope, and, in addition, to conduct much needed research in fields formerly closed by space limitations. The institute is a nonprofit organization.

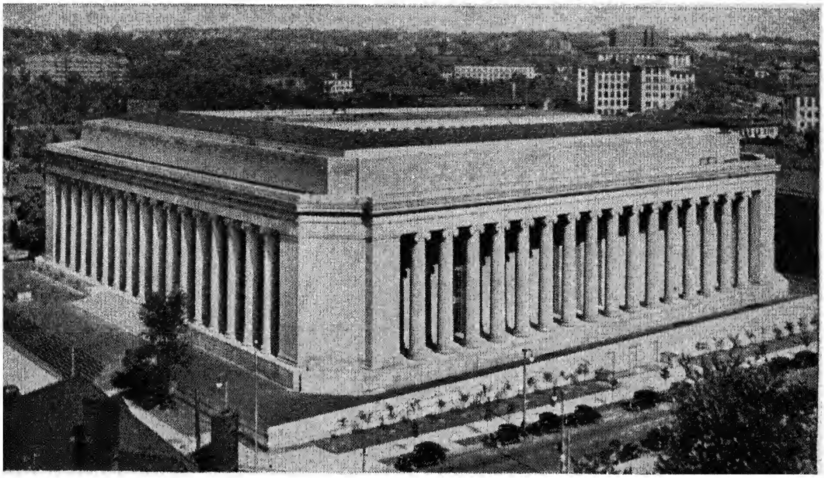
This new building, with all it represents, is devoted to the service of the public good. To the founders, Andrew W. Mellon and Richard B. Mellon, the institute is indebted for constant interest and support since the beginning of its Fellowship System. They realized clearly that, to raise the general level of material and intellectual existence, able scientists must be provided with adequate facilities for research, and they believed firmly that an independent scientific institution, with the sole aim of searching for those truths that are essential to industrial progress and human welfare, would be the highest type of useful gift to the nation. They have enabled a carefully chosen group of scientists to live and to work and so to add to the enrichment of civilization.

Mellon Institute has three major functions: it conducts research in pure and applied science; it trains research workers, affording them unique opportunities for specialized development; it provides technical information adaptable to public advantage.

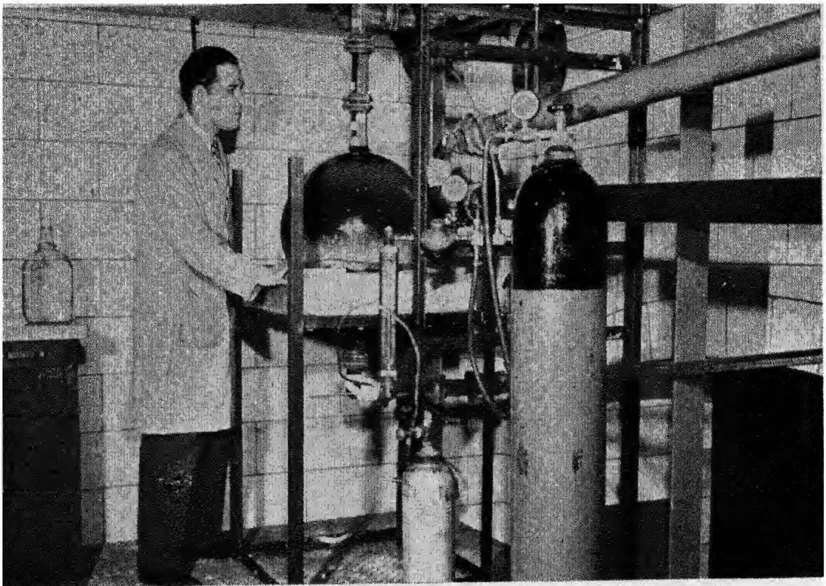
The institute, as it exists today, has grown from a smaller organization that was brought together by Andrew W. Mellon and Richard B. Mellon to develop in Pittsburgh the industrial research procedure conceived by Robert Kennedy Duncan. Believing that industry and science could work in harmonious cooperation, Duncan became convinced that our country would benefit greatly if some method could be evolved to assist industry in employing scientific technology in place of the traditional rule-of-thumb production practice then followed generally. His idea took form in a practical plan for studying long-time industrial problems under the auspices of an educational institution.

In 1907, while Duncan was professor of industrial chemistry at the University of Kansas, he had the first opportunity to submit this concept to actual test. He proved its merit. He was invited by Andrew W. Mellon and Richard B. Mellon to come to the University of Pittsburgh in 1910, to put his idea into effect on a broader scale, and the operation of the Industrial Fellowship plan was begun here in 1911.

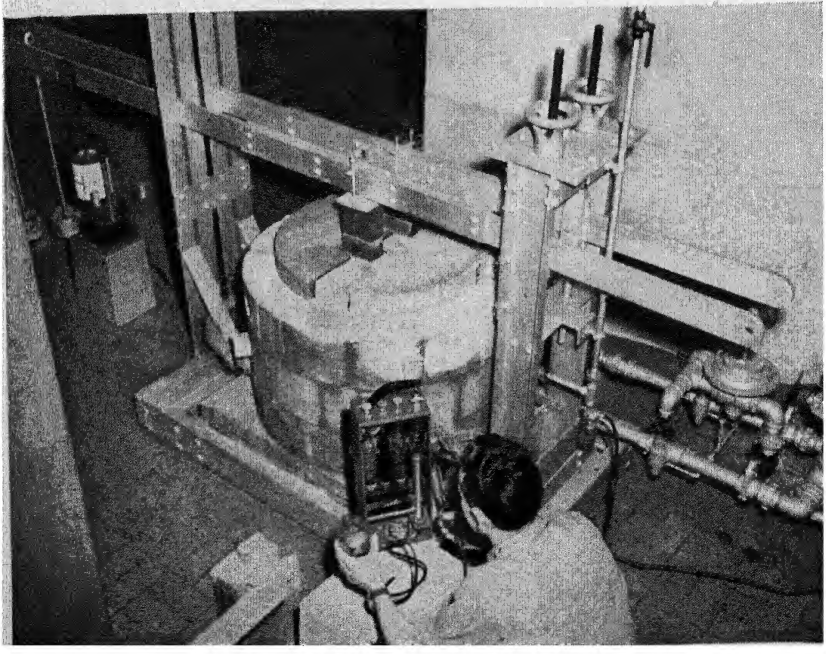
They followed Duncan's progress with close interest and soon became certain that the procedure was sound—that it served both to benefit the public through scientific accomplishments and to train young men for useful research careers. They founded Mellon Institute as such in 1913 and later placed its Fellowship System on a permanent basis. Their broad views of the proper spheres of



The Mellon Institute, Pittsburgh, Pa.



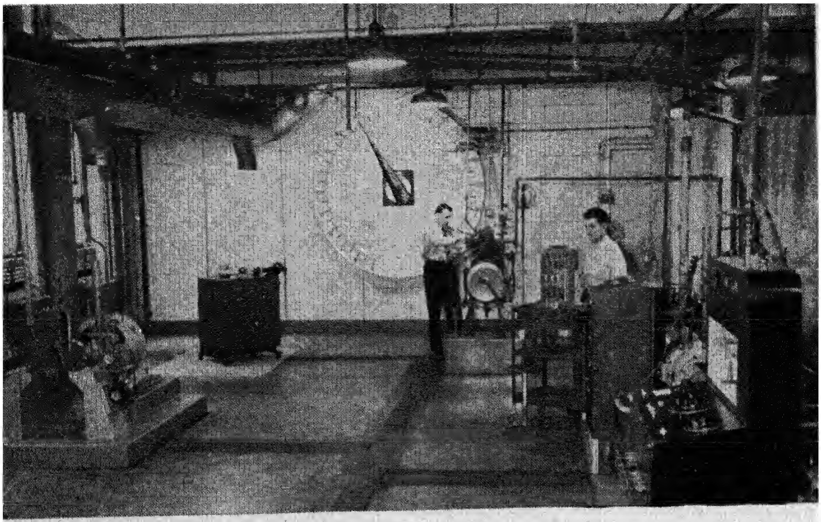
Preparing a new chlorinated hydrocarbon plastic.



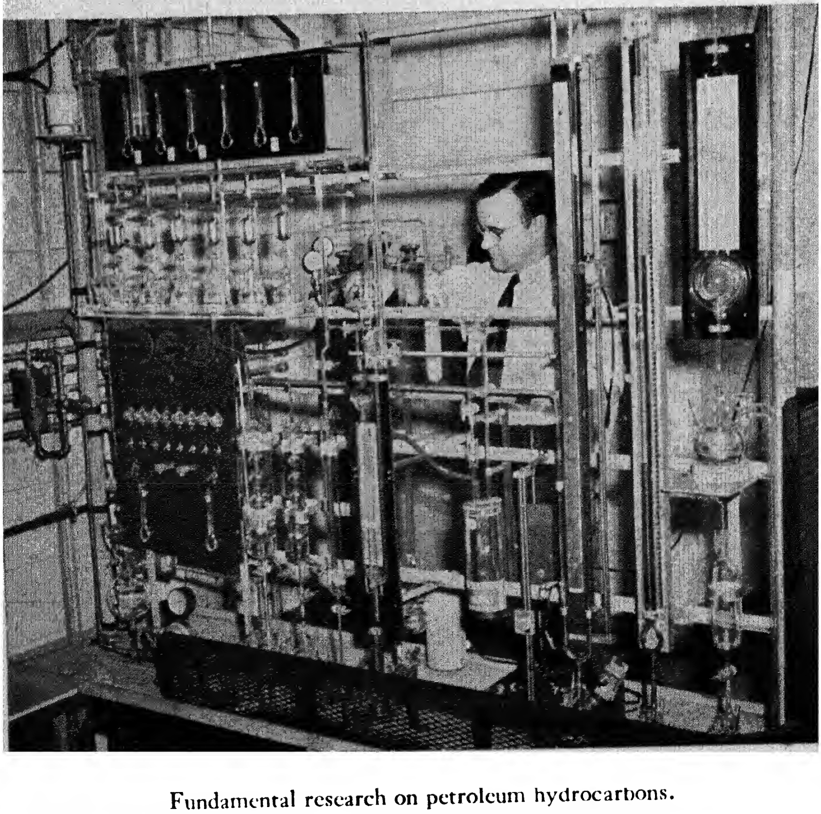
Complete hot-load test on a refractory in research.

Inspecting batch of nickel stearate after preparation in a doubly jacketed and electrically heated nickel reaction kettle.

Casting in the Magnesium Fellowship foundry.



Lubricating oil studies in test engines.



Fundamental research on petroleum hydrocarbons.

service of the institution are reflected in the support they have given to its researches in pure science.

In 1915 the institute moved from its original small frame laboratory into the building that was its home until 1937. The organization carried on its work as a part of the University of Pittsburgh until the institute was incorporated in 1927. Since then its affairs have been managed by its own board of trustees through an executive staff. The institute continues, however, in close cooperation with the university.

Under the Industrial Fellowship System, the various research problems are proposed by firms or associations to meet the needs of their particular fields. If a given proposal is of such scope as to be acceptable to the institute, the investigation is organized under a contract with the donor for a period of at least one year.

The scientific worker, with training and experience that fit him for that particular research, is found and engaged by the institute. He is accorded use of laboratories and facilities, guidance and advice of the institute's executive staff, and cooperative aid of other Fellows. The donor of the fellowship is kept continually in touch with the results of the work. Only one research is carried out on a particular subject at any one time.

On the 82 fellowships in operation during the fiscal year March 1, 1945, to March 1, 1946, there have been 525 senior and junior scientists. The research facilities are kept effective by the servicing staff numbering 175.

The continuity of the institute's research programs attests the soundness of its Fellowship System. Four fellowships have been proceeding 30 years, others at least as follows: four, 25 years; one, 20 years; nine, 15 years;

and fifteen, 10 years. An additional twenty-eight fellowships have completed five years of investigation.

During the 36 years since the first fellowship was established nearly 5,000 American companies have been served by the institute on problems ranging from food and sleep to glass and steel. It has evolved many novel processes and products, some of which have resulted in the formation of entirely new industries. Its contributions to the literature of chemistry and allied sciences include 22 books, 196 bulletins, and 2,157 miscellaneous articles published in technical journals. Its war work is notable.

While the institute is best known as a technologic and scientific experiment station, it has the innate function of serving as a training school in research methods and in special technical subjects. Because it recognizes the need of fundamental scientific research as a background and source of stimulus for industrial research, it also supports disinterested investigations not suggested by industry but planned within the institute and directed toward the study of more basic problems than those usually pursued in technologic researches.

Among the institute's many comprehensive investigations in the realm of pure science, conducted for the benefit of the professions or the public, have been studies on smoke abatement and later on industrial health, research into the cause and prevention of dental caries, a comprehensive investigation of sleep, a project to find a better way to diagnose tuberculosis in its early stages, and a search for new compounds of value in treating pneumonia and malaria.

The work in pure science, carried on since 1911 and formally organized under the Department of Research in Pure Chemistry in 1926, has grown steadily in breadth

and importance. Wider opportunities are had by this function of the institute in the new building. In consequence a Department of Research in Chemical Physics has been added to apply the new techniques in this field in assistance to fellowships and in fundamental studies of its own choice. The results of researches in pure science are, of course, published and widely distributed as they are completed.

Science: Salvation or Destroyer of Mankind?

A Transcript of the TOWN MEETING Broadcast Originating at the George Westinghouse Centennial Forum

Science: Salvation or Destroyer of Mankind?

Announcer:

Welcome to the 422nd broadcast of America's Town Meeting, convening tonight in Pittsburgh, Pennsylvania, in the Syria Mosque Auditorium, where we are the guests of the George Westinghouse Centennial Forum on Science. Leading scientists from all parts of the country are here in Pittsburgh for a three-day session considering the recent momentous events in the field of science.

To conduct our meeting, here is the genial leader of America's most popular radio forum, Mr. George V. Denny, Jr., president of Town Hall, New York.

Moderator Denny:

We're very glad indeed to be a part of this fine occasion honoring the name of George Westinghouse, who was born a hundred years ago this year. Gathered here tonight are the greatest names in science. We always seem to have significant and exciting meetings here in Pittsburgh. Remember when we discussed the fourth term for President here?

Tonight we are asking the scientists if there is going to be a fourth term for mankind, and I hope you'll mark well every word they tell you and then try to read between the lines and try to understand fully what they are saying

to us on this momentous subject, "Science: Salvation or Destroyer of Mankind?"

Nothing that I can say will be half as important as what they'll say. I can only remind you that this is not a debate but a discussion by four renowned authorities about a subject that concerns your very existence. They're not going to talk over your heads and they are not going to talk down. They are going to give it to you straight from the shoulder.

So listen first to what Harold C. Urey has to tell you. Dr. Urey is one of the scientists who helped develop the atomic bomb. He is professor of chemistry at the University of Chicago and is a Nobel Prize winner for his discovery of heavy water.

Dr. Urey:

Strictly speaking, Mr. Denny, science can neither save nor destroy mankind, for it is concerned neither with useful things nor with destructive things. What concerns us tonight is what men do with their knowledge and their skill of all kinds.

Science is an intellectual pursuit and has for its objective the understanding and exact description of natural phenomena of all kinds. But what shall we do with this knowledge? Use it to build material and spiritual things or use it to destroy man and his works?

I shall let Dr. Bundesen and Dr. Waksman discuss ways in which science has saved mankind and will save mankind in the future *if*—and this is the cue to my place on this program.

I could also tell of the great benefits physical science has brought to man, but I am the apostle of doom. I am still a frightened man and I wish you to be frightened.

The gravity of the present situation in the world is frightening beyond our ability to express. It is not possible to exaggerate this situation. All positive benefits to come from science or anything else depend on the solution of the problem of war and particularly of a third World War.

What we are discussing is not a scientific problem. It is a political and social problem. During this century, we have learned much about these technical applications of science, together with methods of mass production, which have developed, with the aid of our large accumulations of capital, to produce materials for the use of men on a scale that has never occurred at any place or at any time in all previous history. With the aid of these things we can give man a material and intellectual existence on a level that has never before been known.

All of us, I think, recognize the truth of this statement, as others on this program will tell you later.

At the same time, we have applied these same scientific and engineering methods to mass warfare, particularly in this century. This application has been so effective that we have brought this civilization to the very brink of a precipice.

We have reached such a state of development in the arts of war that it is possible that another war will destroy this civilization just as many previous civilizations have been destroyed in other ways. Such previous civilizations have risen and fallen, and the people within them lacked the capacity to prevent their destruction.

We may well pause and ask the question as to whether we, the people of the European civilization, have the capacity to prevent our own activities from destroying ourselves and all the great works of the mind that we have developed.

But in spite of my fears, I am not without hope. All of us who are descended from the northern European tribes, and there are few of us whose ancestors did not come partly from that region of the earth, must recognize that 1,500 years ago our ancestors were savages on the northern plains of Europe, who did not leave a history of their own or even a carved monument of any kind to tell us of their mode of life.

During these 1,500 years, we have been able to adopt a civilization from the Mediterranean region and modify it to our uses. We have attained a very high intellectual level. That savage on the northern plains of Europe had the capacity to organize such governments as that of the United States and to build all the marvelous structures that we see about us.

It is my belief that the capacity of this man is still sufficiently great to master the new problems as they come to us.

It is my belief that we will be able to control the atomic bomb and other methods and weapons of war and prevent these destructive instruments from destroying us and all our works. But control of the atomic bomb and other methods of modern war will not come about if we adopt a purely passive attitude toward these things.

If we allow ourselves to drift, another war is inevitable and that war will exceed any wars of the past in destructiveness. It is necessary for us to meet this problem in some constructive manner and we must move rapidly.

We have about five years to work out methods for the control of atomic bombs in modern war. If we do not do this, control will be established by the victor in a third World War—and we may not be that victor.

Every means of any kind that anyone can devise

should be used to prevent war or postpone the outbreak of war and thus give time for the peoples of the world to adjust themselves to the atomic age. Mr. Laurence has some remarks on this subject later.

I am convinced that before the year 2000 a world government will be established on the earth. It will be a government, we hope, with limited powers, but that it will be established is not a point to be argued. The question is, will it be established by agreement or will it be established by means of the third World War. That war, if it is fought, will be frankly for the purpose of determining which group will organize government on a world-wide basis.

We cannot expect that such a social change as this will come about in a constructive way unless we—all of us—give it first attention among all the problems that face us in the twentieth century.

Moderator Denny:

Now we turn to another department in the field of science—that invisible world of microbiology, which has so profoundly affected the destiny of man, without his knowing it, for thousands of years. Listen to the man whose research has opened new doors and windows in this invisible world—an eminent microbiologist, the discoverer of streptomycin, professor of microbiology at Rutgers University, Dr. Selman A. Waksman.

Dr. Waksman:

Dr. Urey has painted a very dramatic picture of what might happen to us if we do not learn to control the atomic bomb. My good friend and colleague, Mr. George Merck, told us this morning of the potential dangers of

biological warfare. My own particular field, as Mr. Denny has said, is microbiology, which is the study of microscopic forms of life, largely invisible to the naked eye. While I do not belittle the potentialities envisioned by Mr. Merck, I believe that actualities are much less dangerous than at first appears.

There are good microbes and bad microbes, and I want to talk to you about the good microbes and their possible effect in controlling the bad ones.

Day by day, year by year, men of science are probing deeper into the mysteries of nature and learning more and more about how to use the great power available to us through the efforts of the scientists—the power that is found in the soil under our feet, in the water of our lakes, rivers, and seas, and in the very air that we breathe.

If you could join me in my laboratory tonight, I could show you through my microscope a whole new world consisting of bacteria, fungi, protozoa, and other fine forms of plant and animal life, as well as the viruses, which are not visible even through the ordinary microscope. These microbes affect our welfare in numerous ways, some being highly beneficial and others injurious.

There was a time when this unseen and mysterious world around us gave rise to pestilence, to plagues and epidemics that influenced history in far greater and in more important ways than the mightiest struggles between armies on our battlefields. The outbreaks of smallpox, influenza, the black plague, and cholera have profoundly affected human history. Typhoid and yellow fever, diphtheria, typhus, and the various venereal diseases, once the scourges of mankind, can now be conquered by men of science who know how to control them.

By now, most of you have heard of penicillin and of

streptomycin. These are new tools discovered by man for treating many diseases, and are products of the microbes themselves—the food microbes.

The scientists have a $10 word for these chemical agents from which the beneficial microbes have been harnessed or domesticated, "antibiotics," which simply means products of microbes that are able to destroy other microbes. These, together with the sulpha drugs, the vaccines, the serums, serve to eradicate further the dangers from human infection and epidemics.

Now let us look at the war. Can microbes be used as a weapon in warfare?

This has been suggested on several occasions—by inoculating the water with typhoid, with dysentery, or with cholera germs; by infecting the atmosphere with a variety of viruses and other disease-producing agents and the wild and domesticated animals with plague or with acute and deadly infections. By spreading a variety of blights, destructive insects, and fungi over crop areas, it would be possible that bacteriological saboteurs could ravage large sections of the country and cause inestimable damage to human health and welfare.

The equipment required for this purpose could be carried in small containers or the infective agents dropped from planes. The troops of the terrifying Spanish conqueror Pizarro are said to have presented the Indians with clothes from smallpox-infected patients, resulting in the death of 3 million Indians.

Various rumors reached us during the war that has just ended that the Japanese actually used plague and cholera germs to infect rats and other wild animals in order to spread diseases among the Chinese.

Fortunately, however, the danger envisaged is far

greater in theory than in reality. As Dr. Bundesen will tell you, water treatment commonly practiced in our cities, methods of sanitation, and means of prevention of infection and epidemics now available would tend to eliminate most, if not all, of these potential dangers.

Man is now well willed to combat and control injurious microbes that may be willfully imposed by his fellow man. The possibility of great danger from disease and epidemics is always with us.

The deadly microbes are not dead. They will always be with us and become actual dangers when given a chance, willfully or through sheer ignorance. With the help of science, man has learned to control them, to combat them, and to confine them to the laboratory test tubes, where they can be carefully watched over by the microbiologists.

If they are ever taken out of the laboratory and used as weapons, as destroyers of mankind, this will be the work of governments, not of scientists, and let us pray that it will never happen. But if it does happen, the scientist is prepared, if given a chance, to meet this dangerous world and try to find weapons to combat these new potential dangers.

Moderator Denny:

Now listen to the counsel of a man whom the War Department chose to witness and explain the development of the atomic bomb to the world at large—Mr. William L. Laurence, science writer for the *New York Times*, who has just won a Pulitzer Prize for his work in this field.

Mr. Laurence:

On July 1 this year there will take place on Bikini Atoll in the Marshall Islands the first test on the effect

of the atomic bomb on ships. The test and the two tests to follow are appropriately named Operations Crossroads. For it is true in every sense of the word that civilization, as we know it, stands at a crossroad, and that mankind is now faced with the most momentous decision in its history on this planet.

Like Hamlet, mankind as a whole, or at least that part of it rightly or wrongly named "civilized," is now faced with the question "to be, or not to be."

I agree with Dr. Urey that the next five years, maybe the next five months, or less, may give the answer.

It all depends on what man decides as to the future of the atom. If he is going to use it for bombs, the answer is definitely "No." If he decides to use the vast power within the nucleus of the atom for his benefit, then the answer is a resounding "Yes."

Whether science is to be the salvation or destroyer of mankind depends not upon science but, as Dr. Urey says, on politics. It all depends on the question of war and peace. The word "war" has now become synonymous with suicide. The word "peace" is now a synonym for survival.

We are witnessing a race against time between the forces that work toward the salvation of mankind through science and the forces that work toward its destruction.

In the past, we had time to catch up. We could let ourselves remain defenseless until the last minute, content to wait until we were in danger and then we could mobilize all our forces.

What the atomic bomb has done is to kill time as well as cities and men. If there is be a third World War, there will be no time to build ships and tanks and guns and planes, because in an atomic-bomb war it would be

a matter of seconds and minutes or hours, and it would all be over.

On the other hand, if the decision is for peace, man has it within his power to realize the dream of the ages. After a million years of existence on this earth, he has at last managed to find the key that unlocks the basic energy of the cosmos, the vast treasure house within the nucleus of the atom.

He has the means to remold his world into a land of abundance and plenty for all, a world in which war would be unthinkable, provided he does not in the meantime destroy himself.

From time immemorial man has sought for means to conquer time and space. Atomic energy promises to bring him much closer to the fulfillment of this ancient quest, for he now has at his disposal a tool that can serve both, as the long-sought-for philosophers' stone, to create new elements more valuable by far than any gold, and as the equally legendary elixir of life for the conquest of disease and the prolongation of life beyond his allotted life span.

The modern name for this philosophers' stone and the elixir of life is "neutron." It is the fundamental neutral particle of matter residing within the nucleus of the atom.

It would take a long time to bring about the beneficial use of atomic energy for mankind if man chooses, but the means are here today and a start can be made immediately, provided the proper measures are taken to utilize what we already have.

Right now we have three great atomic energy plants. These plants are now producing material for atomic bombs. They are also liberating vast amounts of atomic energy that is now going to waste.

In addition to liberating this vast amount of energy, these plants also liberate vast streams of neutrons. Scientists all over the country stand ready and waiting to use these neutron streams for the creation of new elements that could be used as powerful searchlights into the unknown and as immensely valuable new substances for fighting disease. Yet for the present very little is being done.

Until Congress decides on a policy as to what to do for the peaceful development of atomic energy, present authorities are helpless. Congress is waiting for the people to tell them what to do. It is up to all of us to let Congress know just what our wishes are in this matter.

I agree with Dr. Urey that a world government is the eventual solution of the problem of war and peace. But I also feel that a world government would take too long a time before we could prevent another war, which would mean an atomic-bomb war.

Therefore, I think that along with a long-range plan for a world government, we should also have a short-range plan for the control of atomic energy in the interim period, while we are preparing for the desired goal.

Moderator Denny:

Now, let us hear from a man who has devoted his life to the prolonging of the life of others, the Health Commissioner of our country's second largest city, Chicago, syndicated columnist, and health editor of the *Ladies Home Journal*, Dr. Herman N. Bundesen.

Dr. Bundesen:

Mr. Laurence, I agree with you that if civilization is to endure, atomic energy must be harnessed in the service of mankind.

I am in complete accord with Dr. Waksman's views that the scientist, if given a chance, can and will control the deadly microbe, and the most hopeful thing about science is that it shows itself as the two-edged sword that it truly is.

And, Dr. Urey, I'm so glad that you have emphasized the fact that we no longer live in the fool's paradise of belief that the mere progress of science, unbridled, will bring salvation to mankind.

The atom bomb has proved that it can wipe out millions instantly. But against this science so dark with power to destroy us utterly there is another science, bright with the gleam of promise to forge a stronger and happier humanity.

My own life has been devoted to helping those who are sharpening this bright edge of the science against misery and death. Forty years in this battle have brought me deep faith that if we tell all of the people of the world of this beneficent science, showing them the good life that it can bring, this cleansing beam of universal knowledge will guide them toward control of the evil science, the one that at present seems to be the more powerful.

The need to start this good war is desperately urgent. Yes, Dr. Urey, if we dally for five years, or even one year, it may be too late. But admitting that our backs are to the wall, how, then, can we begin the use of science against mankind's destruction and for his salvation?

First, by facing the fact that our lawmakers have been generous in support of the evil edge of the sword of science, but niggardly in the aid of the science that will light our way out of the world-wide hunger, and sickness, and misery, and death.

Take development of the atom bomb. In six years, $2,000 million were gambled to make a reality of the most

horrible instrument of destruction in all the history of the world. No sum even faintly comparable has in a lifetime ever been devoted to the development of weapons to fight for life. It's the soldier, not the doctor, who had the ear of the rulers until now.

I'm not charging our leaders in power with malevolence. They doubtless believed they had to fight fire with fire. But, again, we must face a fact—it's that our rulers don't know, and don't know they don't know, the search toward life and brotherhood that would follow if only they would give our scientists full use of the weapons, already available, to wipe out diseases that are now killing needlessly myriads and to unravel the causes of the greed and the mass insanity that give rise to wars.

In my own time and experience, I've seen deathlike typhoid and diphtheria all but conquered. I've seen the dying of mothers and little babies in childbirth cut down far below what used to be considered the irreducible minimum.

But these are only partial triumphs. So powerful has life science become in these various years,when we thought death science was invincible, that it is not too much to say that an essentially disease-free mankind is now in sight. If bombs can destroy whole cities, we can wipe out whole deaths from the face of the world—and I don't mean maybe.

Again, out of my own experience in the city of Chicago, one-tenth the sum devoted to the development of the atom bomb would go a long way toward wiping out the curse of venereal diseases from our nation. Similarly, modest expenditures would make tuberculosis, pneumonia, and the other master killers hardly more than evil memories, and what a world that will be.

Weapons are already at hand to save one-third of the 160,000 who needlessly perish from cancer every year. Only the other day a fine young scientist showed me how we could wipe out rheumatic heart disease, very likely within ten years. Organic chemists are giving us new vitamins and hormones, promising control of the degenerative diseases of the arteries and prolongation of the prime of life.

Why don't we follow through and learn more about this? Is it only a beautiful dream? Is it because it's too expensive? The answer is—it costs far more to die than it does to live!

QUESTIONS

Mr. Denny: Now, gentlemen, I don't know whether you've stirred up enough difference between you to have a discussion around the mike, or whether we'd better go into the audience for questions. Dr. Urey, do you think we've got some difference of opinion here? Would you like to ask a question of the others?

Dr. Urey: Dr. Waksman and Dr. Bundesen seem to think that the beneficial uses of science are sufficiently curative for the destructive effects of science. I should like to ask them what they think is the solution to this modern technological war. How are we going to prevent that destroying all the useful things of science while it destroys itself?

Mr. Denny: I think you were the man who carried the burden there, Dr. Bundesen. Perhaps you'd better comment.

Dr. Bundesen: Two thousand million dollars for instruments for the destruction of life! Let's spend the next $2,000 million for the development of weapons to fight for life!

Mr. Denny: Does that answer Dr. Urey's question, Mr. Laurence?

Mr. Laurence: I hardly think so. After all, we've all agreed with that, but how are we going to bring it about, Dr. Bundesen? That is the problem that confronts us all. We all would like to see that, of course. Tell us how.

Dr. Bundesen: We must expose these things to the cleansing light of universal knowledge. How did they get the $2,000 million against life? If we can do that same thing, let's get it for life. It was there.

Mr. Denny: Dr. Waksman, have you anything to add?

Dr. Waksman: My problem, as I mentioned, was biological warfare. Certainly, we must be protected. We must be prepared to defend ourselves against it. And in preparing so, no doubt the rest of us will benefit from their expenditures, but I truly agree with Dr. Urey in the great dangers of an atomic warfare.

Dr. Urey: You see, I think, this problem is not a scientific one. No expenditure of money in one way or the other for science will solve the problem. It is a political problem. The world is in anarchy. It can only be saved from anarchy by the establishment of law. One can only get law by having established governments. This is my answer to the problem of how will we prevent the atomic bomb, and many other things, from destroying us, and not bringing us the great benefits that we all desire.

Mr. Laurence: I would like to ask Dr. Urey whether or not he doesn't think the danger of being destroyed by an atomic bomb within the next five or ten years is not greater than the chances of getting world government within that period.

Dr. Urey: I think the most likely course of history is that we will have an atomic-bomb war. I would bet my

money on that, if I thought it was worth while. Winning wouldn't be worth while. At the same time, the only solution for this problem is a limited world government. Perhaps it could be very limited. It is the only solution I know of. Probability low or high, I must work for the only thing that looks like a solution to the problem.

QUESTIONS FROM THE AUDIENCE

Dr. Urey, Dr. Bundesen said that the atomic bomb cost $2,000 million. Will you make it clear that that was the amount spent for the development of the bomb; that the bomb did not cost that much; that the bomb will save men and airplanes? Will you tell the audience how much is lost when a plane is shot down?

Dr. Urey: Yes, I can make a statement of that kind. Of course, the first atomic bombs cost us $2 billion total, and we only dropped two in this war. You might think that was $1 billion apiece. I don't know what an atomic bomb would cost in the course of years if we tried to get the cost production down low, but I should think $1 million or $2 million, somewhere in that neighborhood, would cover the cost. It's the cheapest explosive we have, considering the destruction it does.

Mr. Laurence, is not the production of atomic energy the finding, you might say, of God's own secret of the creation of His nature? Isn't this a terrible secret for a common man to have?

Mr. Laurence: Not at all, everything else is a part of God's own nature. There is no difference.

Dr. Waksman, the war has been over for about a year. Now, why is it then that the information on biological

warfare has been kept such a dark secret until just this morning, when Mr. Merck revealed it here before the George Westinghouse Centennial Forum? Why has it been kept such a dark secret?

Dr. Waksman: I will try to answer this question, although I have not been concerned at all with either the development of biological warfare or with keeping it a secret. Biological systems work far slower than chemical reactions. There is no doubt that it took years to discover certain biological principles, whereas chemical reactions can be worked out in a much shorter period of time. Therefore in order really to answer the question, it may have taken that much time.

Dr. Bundesen, you seem to feel that the lawmakers of the world are responsible for our future salvation. What can we do to stir up our Congressmen in these United States?

Dr. Bundesen: I think sickness, misery, death, are all things that maintain themselves always on public ignorance and public indifference. I, too, think that when you expose these things, as you do in this fine Forum here, to the cleansing light of universal knowledge, conditions will be solved.

I am sure that if enough people show interest—if not now, at the next election time—for what they want, they'll get what they want.

Mr. Laurence, knowing of the frequency of wars between nations, is science charged with this condition or are political ambitions of nations or factors within nations guilty?

Mr. Laurence: Well, that's a question that would be very difficult to answer, but whatever the causes of war we should try right now to eliminate them because war no longer will pay either the victor or the loser. There will be no victor in the next war, so, whatever the cause, it would still be a nonpaying proposition and by making that clear then it wouldn't matter what the causes are.

Mr. Denny: Remember the Southerners—and being a Southerner I can say this—the Southerners used to say that we could have licked the Yankees with cornstalks but they wouldn't fight that way.

Dr. Urey, how do you propose raising a police force to support your world government?

Dr. Urey: The problem of securing international control of the atomic bomb and warfare involves, first of all, taking temporary measures as may be necessary, as Mr. Laurence says, to give us time. Then we must expect to establish a government that has executive, legislative, and judicial powers. With the executive, of course, would go the usual police powers. Not an army—an army isn't a police force. It is distinctly different. A police force works within law, an army works outside of law. It will have to tax the population directly. It must make laws for individuals and not for states—you can't coerce a state except by war. These things take time. I think it is possible that we can obtain it without war, but maybe not.

Dr. Waksman, do the military leaders of this country realize that biological warfare, perhaps, holds greater terror for mankind than atomic warfare? And if so, would anything be gained by conducting biological warfare tests on a scale that is comparable to Operation Crossroads?

Dr. Waksman: It is very difficult to compare the effectiveness of biological and atomic warfare. As a matter of fact, atomic warfare has been tested and found to be highly destructive. Biological warfare has never been tested on any scale comparable to warfare at all. Small tests seem to indicate that it can be very dangerous and very destructive.

However, as I indicated in my presentation, the scientific workers—the scientists—have learned many methods of control of biological warfare, and, given time, they will, no doubt, find ways of controlling the new ones. It takes time, and, meanwhile, it can prove highly destructive.

Mr. Laurence, I should like to ask you, if you believe that science is the destroyer of mankind, would you therefore conclude that scientific research should cease or would you rather say that scientists should redouble their efforts to provide answers to world dissatisfaction that cause wars?

Mr. Laurence: I certainly would advocate the continuation of scientific research. I certainly don't believe that it would be possible even if it were decided to stop it because you can't stop the human mind from functioning. What I am saying merely is that science could save civilization, could bring about a millenium, provided doomsday is not brought about first by those who misuse science.

Mr. Denny: Yes, Dr. Urey?

Dr. Urey: I would just like to raise the question about stopping work on science. Do you mean just in the United States or do you mean also in the rest of the world? If you mean in the whole world, how do you propose to do it?

Dr. Urey, do you feel that the reasons that prompted nations not to use poison gas in this past war will also cause them to withhold the use of the atomic bomb although they may have it, in the future?

Dr. Urey: The answer is emphatically "No." I am doubtful in regard to the reasons for withholding poison gas, but I suspect that the reason was that it was not so effective as incendiary bombs. If the whole world has atomic bombs, we'll all become pathological. We will live in fear, night and day. We will not be rational. We will be highly irrational. Each one of us will think that we ought to start the atomic-bomb war today before the other fellow starts it tonight.

Dr. Bundesen, as civilization contemplates the unspeakable horrors of the Axis concentration camps, do you not think it was a bargain that we won the war on $2 billion?

Dr. Bundesen: I have no quarrel with the $2 billion that was spent. All I say is let's also spend another $2 billion to save humanity from the other diseases, that we can, that are available and ready to be controlled. I've no quarrel with the $2 billion that was spent. That was all right, but let's spend equal amounts to take care of many of these preventable conditions that the discovery of the atomic bomb now is bringing forward as a solution of our problems.

Dr. Urey, how are you and other scientists throughout the world striving for progress and survival when you use your talents for inventing bigger, better methods of destruction?

Dr. Urey: I was asked that question in Detroit and I asked if all the citizens of Detroit that helped to make tanks felt any sense of guilt because they did so. We're all caught in the web of war. None of us can keep out of it when we once start a war.

Dr. Waksman, would putting the control of scientific findings in the hands of scientists in their respective fields not result in nondestructive application of the findings?

Dr. Waksman: The scientist never works with the purpose of destroying. He works for the purpose, first of all, of discovery and, secondly, hoping that his discovery will be for the good of man.

Mr. Laurence, science can produce. Now it's largely up to us what we do with what science has given us. If we put as much effort in trying to win the peace as we did to win the war, can we not have a lasting peace and united world?

Mr. Laurence: I hope you're right. But we are not working very hard toward that aim, in my opinion.

Dr. Bundesen, don't you think that the $2 billion spent for the atomic bomb could be used for—the energy could be also used for—medicine for your purposes, too?

Dr. Bundesen: The scientists here that have talked to you can better answer that question and already have better answered that question. That is just exactly what we'd like to get the $2 billion for—or whatever it takes.

Dr. Urey, do you expect the bomb could have been developed in the length of time had the war not been present? In other words, do you think that you would

have gotten government help for expenditures of the development of atomic energy in peacetime?

Dr. Urey: No. No, not at all. I think it might have been much better—it might have been—of course, this "might have been" is a very unsatisfactory expression. Omit it. We only know what happened. But I don't think we would have gotten it for peacetime purposes.

Mr. Laurence, consider history; science made tremendous strides in twenty centuries. Man's position with respect to salvation changed negligibly. Aren't we overestimating this tremendous danger of science?

Mr. Laurence: We are not at all. No, we have just reached a point where all the research and knowledge accumulated in the 2,000 years—or rather 10,000 years or say even 500,000 years—we have now reached a point where we have liberated the force that has the power to destroy us in a very short time. Up to now, the forces of salvation, you might say, and the forces of destruction were about evenly balanced. In fact, until about 25 years ago, the beneficial forces were greater—were outbalancing the destructive forces.

But now the tables have turned. The destructive forces are way ahead, and will be unless something is done to check them, and it has to be done by all men living today, because it is everyone's problem.

Dr. Bundesen, can science further advance the people's welfare while shackled by the artificial production controls and stifling patent restrictions?

Dr. Bundesen: I don't think that anything ever can shackle science. It will go on and on and on, no matter what tries to hold it back. It may be retarded a little bit but sooner or later the true things will come up if you

want them hard enough, and long enough, and strong enough.

Dr. Urey, must scientists wait for word from Congress before they start adapting atomic energy to constructive uses in industry, health, and fuller living?

Dr. Urey: Such efforts are going on at the present time and a certain amount of effective work is being done. I do not think that we will attain the maximum development of atomic energy for either peacetime or military purposes until we get the legislation through Washington that is now proposed, establishing a stable atomic energy commission, which can set policies for a long period ahead and can move with confidence.

Mr. Laurence, will not communism bring a better set of circumstances so that we can have the brotherhood of man and use science for the benefit of all?

Mr. Laurence: Well, I'm sorry I'm not a prophet.

Dr. Bundesen, if our financial conditions control business conditions, and our business conditions control the temper of the people in the world and create wars, why don't we do something about that before we have to have atomic war?

Dr. Bundesen: Long ago, I learned that if I didn't know, it was a good policy to say I didn't know, and the greatest difficulty is when you try to answer something that you don't know. So if you don't know, and you know you don't know, then get somebody who does know, and you'll never get into trouble.

Mr. Denny: I'm afraid we'll have difficulty finding anybody who would say that they knew the answer to that particular question. Now, this isn't exactly a debate,

and our speakers appear to agree on a number of points, so we have prepared a summary here on behalf of all of the speakers, and I give it to you as their spokesman:

The answer to tonight's question, "Will science save or destroy mankind?" lies not in the scientists, but with you, the people, and your governments all over the world.

The scientists are daily probing into the mysteries of nature and are finding means to both prolong and destroy life more effectively and more efficiently than ever before. Dr. Urey and Mr. Laurence have emphasized the tremendous urgency—we might say the terrifying necessity—for us to find political means of bringing atomic power under controlled world law. Dr. Waksman and Dr. Bundesen do not dispute the facts set forth by their colleagues, but they would have us look at the good edge of this two-edged sword and restrain the hand of those who would use the bad edge to destroy us.

Indeed, Dr. Waksman feels that, while there may be no defense against the atomic bomb, there are defenses, either developed or potential, against biological warfare, and this, at least, is a hopeful sign.

With one accord, they say it's up to you, the people of America, and the people all over the world, and may I point out that if we are to find the right answers to these perplexing problems, we must use our minds with the same integrity that the scientist uses when he closes the door of his laboratory behind him.

We seek for universal truth in the realm of physical relations, as we must seek for universal truth and justice in the realm of human relations. We can no longer afford the luxuries of intolerance, prejudice, greed, and ruthless nationalism. We are living in a new world of science, and this two-edged sword is in our hands—yours and mine.

George Westinghouse
1846 • 1914

A BIOGRAPHY

BY

LOUIS M. STARK

George Westinghouse
1846 • 1914

In the years between the end of the Civil War and the First World War, the industrial revolution in America had its greatest and fullest development. It was during this half century that the foundations for the modern industrial age were laid, and it was during this period that George Westinghouse made his great contributions.

Born on October 6, 1846, George Westinghouse received his first patent in 1865, three weeks after his nineteenth birthday and six months after Lee's surrender at Appomattox. His last patent was issued in 1918, four years after his death and less than a week before the Armistice. Between those two patents were 359 others, many of them revolutionary in principle. They were the monumental expression of a creative genius who responded to a growing America with a complete understanding of the time and far-reaching, practical ideas to meet its need.

His inventions hastened the growth of railroads when they were becoming the economic life line of the nation. He devised the first effective means for stopping trains—the air brake; he pioneered in the development of railway signals and interlocking switches; he invented a safe and efficient mechanism for joining railway cars; he brought out the first main-line electric locomotive and was a pacemaker in modern railway electrification.

When the nation's industries needed power, he developed a system for transmitting and using natural gas, and topped this with perhaps his greatest contribution of all—today's alternating-current system of generating, transmitting, and utilizing electricity for power and light.

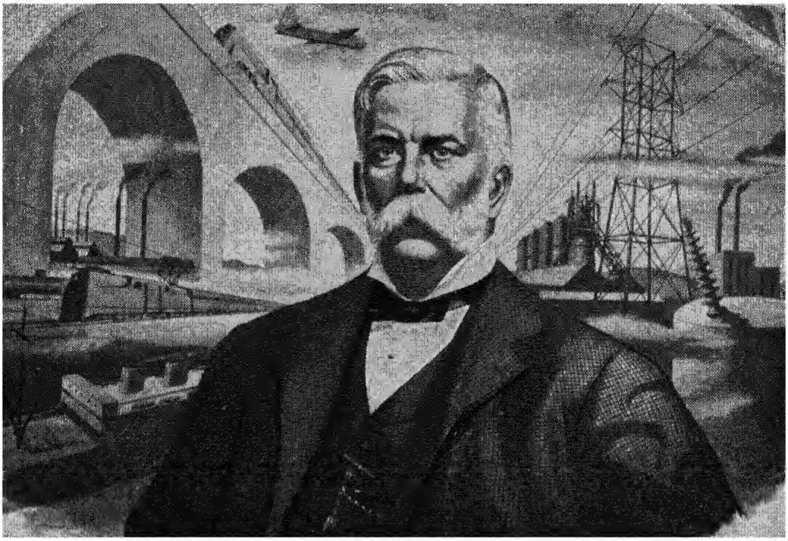
To modern world commerce he gave a perfected steam turbine geared to drive ships, and with this paved the way for the development of powerful present-day fleets.

Westinghouse was not only an inventor—he built what he invented. In the course of his career, he formed and directed more than sixty companies to implement his ideas, and the impact of his leadership radically changed the course of industrial history.

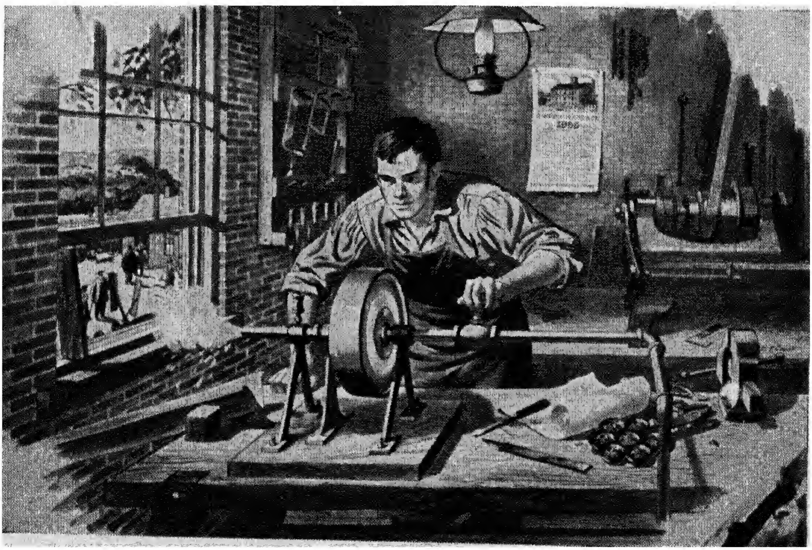
Today—one hundred years after his birth—scarcely a man lives in America whose life and activities have not been affected by what George Westinghouse did. His work and the work of his companies are part of the very structure of the nation's power systems, of its industry, and of every modern form of transportation.

The head-on collision of two freight trains between Schenectady and Troy, New York, was just "one of those accidents that could not be avoided." The engineers had sounded the screaming "down brakes" whistle. The brakemen had rushed to apply the brakes. They had worked as rapidly as possible, but, in spite of their frantic efforts, they could not check the might of moving steel. Now the two locomotives lay crushed against each other. The cars behind them were twisted wreckage, their cargo of machinery, clothing, and food littering the roadbed—years of labor destroyed in one disastrous moment.

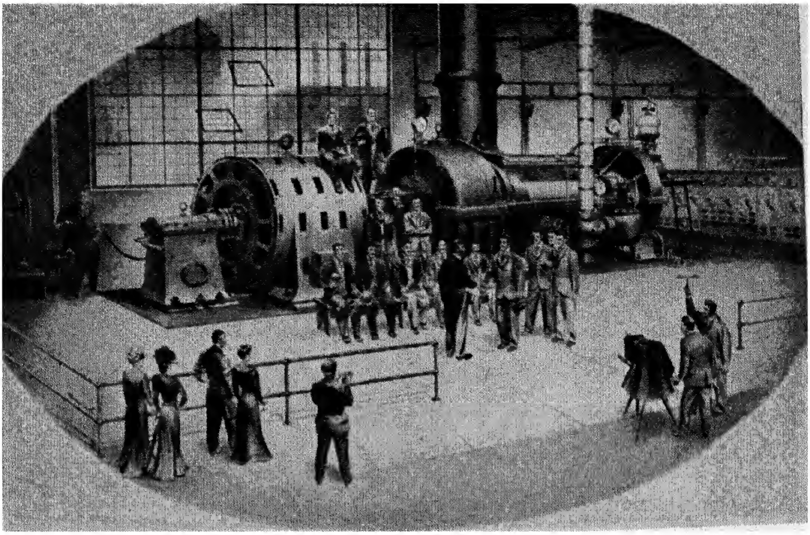
A short distance behind the wreck, a Troy-bound train jerked to an unscheduled halt. Passengers poured



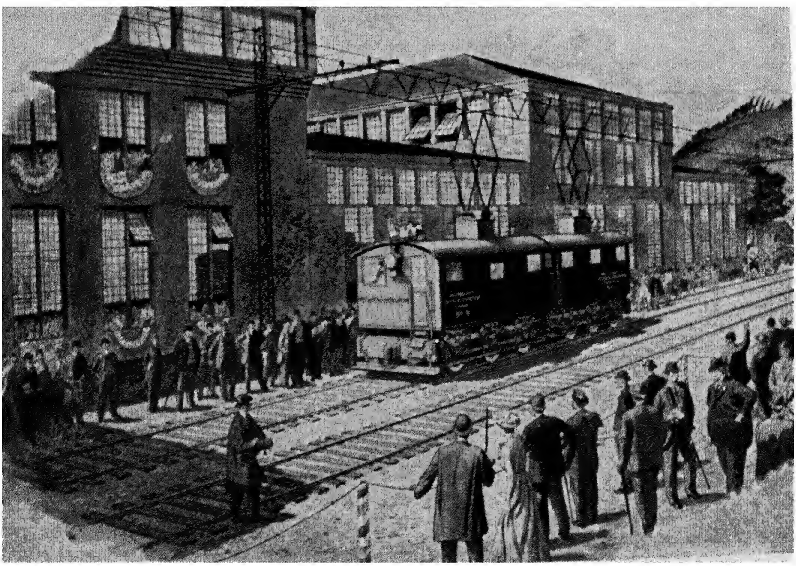
The keys to progress left to all mankind by George Westinghouse have opened many doors—will open many more.



Young Westinghouse develops his first invention—a rotary engine in his father's farm-machinery shop.



Westinghouse's engineers set a precedent with the installation of a steam turbine-generator at Hartford.



Railroad history is made with the successful test of the Westinghouse alternating current locomotive.

out and gathered about the excited trainmen to hear the story of the accident.

Among them was a tall, well-built young man of twenty, who was something of a railroad man himself. As a matter of fact, young George Westinghouse was on his way to Troy, New York, where his invention for replacing derailed cars was being manufactured. For him this delay meant breaking an important appointment, but it also marked the beginning inspiration of his first epoch-making invention.

"You can't stop a heavy train in a moment," one of the trainmen explained to him. And in 1866 that was especially true. Ordinarily, the "down brakes" whistle was sounded a mile ahead of the train's scheduled stop. Then the engineer shut off the power and let the locomotive coast while the brakemen brought the train to a stop. If they were skillful enough and if their teamwork was perfect, they might succeed in making a smooth stop at the right place, but chances were against it.

Each brakeman had to turn a horizontal handwheel that tightened a chain under his car and gradually forced heavy brake shoes against the wheels. Invariably, some brakemen would slow up their cars faster than others, with the result that a stop was seldom made without considerable bumping and jostling. And at the last moment, the engineer had to lend a hand. If he thought the train would stop short of its destination, he opened the throttle and drove it the necessary distance. If he thought the train might overshoot its mark, he "plugged" the engine, throwing it into reverse.

No, you couldn't stop a heavy train in a moment that way. But what if the engineer could control all the brakes in the train himself? Then there would be no dangerous

delay between the time the whistle blew and the time the brakemen succeeded in applying the brakes. Then all the brakes might be applied promptly and uniformly, and the bumps, jolts, and uncertainty might be eliminated. Then, perhaps, accidents like this might be avoided.

George Westinghouse was still a beginner at railroading, but these thoughts at the scene of the wreck were no idle notions in a young man's head. He had already acquired a realistic sense of tools, materials, machinery, and structures, and for years had been planning and making mechanical devices in the shops of G. Westinghouse & Co. in Schenectady, where his father manufactured agricultural machinery.

As a boy, he had spent many of his playtime hours designing and building little gadgets and devices. His contrivances were frequently left incomplete as his attention became absorbed by newer or more intricate machines, and as a rule they were periodically consigned to the scrap heap as so much trumpery by his father. But in a little den in the loft of the factory, young George continued to plan and build whatever took his fancy; and bit by bit he developed his power to shape ideas in metal.

The love of tinkering and building continued during his service in the Civil War. He was only fourteen years old when the war broke out, but he was big for his age and wanted to be in the fight. At first he attempted to run away, knowing that his father would not give him permission to go. He got as far as the train going east from Schenectady and was waiting for it to pull out, when the last-minute arrival of his father spelled an end to the adventure.

For two years he waited, working in his father's factory, until finally, just before he was seventeen, he enlisted

as a private in the cavalry. He served for two years, and then, in 1864, after passing an examination with marked distinction, he was made Acting Third Assistant Engineer in the Navy. Here he returned to his beloved machines. A boyhood friend had lent him a lathe, which he kept on shipboard, and in his leisure hours he pursued his former pastime of turning out mechanical contrivances.

Westinghouse returned to Schenectady matured and deepened by his wartime experience, and in September, 1865, registered as a sophomore at Union College. Within three months, however, he had convinced himself and his teachers that the usual college curriculum had little to offer one of his mechanical leanings. When Christmas vacation came, he left college once and for all and returned to work in his father's factory and to experiment in his den in the loft. Only one important thing had happened to him during his stay in college: on October 31, 1865, he obtained his first patent, for a rotary steam engine.

During the next year, Westinghouse did some traveling in connection with his father's business, and it was on one of these trips, as he was returning from Albany, that he conceived the idea for a device to replace derailed cars—his first really practical invention. The rear cars of the train just ahead of his had jumped the track, and for two dreary hours Westinghouse had to wait and watch the crew inch the cars back to the track and jack them up. Why, he thought, couldn't the men have clamped a pair of rails to the track and run them off at an angle to the wheels of the derailed car?

To Westinghouse, the problem offered the same challenge as his childhood plans for strange engines and gadgets. But now there was the added zest of knowing that such a device was really useful and necessary. It was not

long before he had made a model of his car replacer and had formed a business with two men in Schenectady, who put up $5,000 each to finance the manufacture of this new invention.

Though only twenty years old when he invented the car replacer, Westinghouse had set a pattern in its conception, development, and manufacture that he was to follow for the rest of his life. First there was his awareness of a need for a new device or a new method, frequently before the possibility or even the need became apparent to those who would benefit most from his work; then the concept of a method for meeting the need, which acted as a challenge to his inventive imagination; and finally a business enterprise to turn his ideas into products.

Westinghouse's car replacer was a small beginning for what was to follow. His vision and awareness increased with the years, and his solutions for the needs he discovered were often revolutionary. The sixty-odd business enterprises he founded in the next half century eventually reached into every civilized nation, and the products developed under his leadership have come to benefit virtually every civilized person.

To anyone who in 1866 could look ahead, it was obvious that a good method of stopping trains promptly and efficiently would be a tremendous benefit in the growth of the railroads. America was expanding rapidly. Its factories were turning out more goods. Its network of railroad tracks was becoming more complex, and soon the time schedules of trains would have to be more exact. An efficient braking system would solve the major problem of increasing railway traffic.

Not many men, however, wished to cope with a problem of such dimensions. They contented themselves with

the easy attitude that you couldn't stop a train in a moment, and every day the efforts of brakemen proved them correct.

Westinghouse's plan was to take the responsibility out of the hands of brakemen and put it into the hands of controlled mechanical power. But how? His first idea was to connect the brake chains with the couplings that held the cars together, so that when the engineer applied brakes to the locomotive, the force of the cars themselves as they crowded up on one another would be used to apply the car brakes. A little experimentation on a model in his shop soon convinced him, however, that this was not a satisfactory answer.

Next he considered one long chain connecting all the brakes in the train and operated by power from the locomotive. He was turning this idea over in his mind when business took him to Chicago. There he happened to meet another inventor, who had already patented a braking mechanism based on this principle. The chain connecting the brakes was pulled tight when a windlass holding the front end of it was pressed against the turning wheel of the locomotive. Westinghouse thought the windlass a clumsy arrangement and toyed with the idea of a steam cylinder to take its place. But although this might be satisfactory for trains with four or five cars, it would not be practical for longer trains, since the chain would become so heavy it would require a steam cylinder almost as large as the locomotive itself! He might get around this by having a separate steam cylinder under each car; but then in cold weather the steam from the locomotive would condense and perhaps even freeze in the pipes before it could reach the cylinders of cars toward the rear of the train.

Westinghouse was narrowing down the possibilities, but so far he had considered only the power readily available on a train—the force of the cars jamming together and the steam generated in the locomotive. In those days, before the almost universal usefulness of electricity had been discovered, there were not many other sources of power to which he could turn. But whatever he used to push the brake shoes against the wheels had to be easily and accurately controlled by one man in the cab of the locomotive and it must have tremendous force.

The solution to the problem came in an unexpected way. During lunch hour at the Westinghouse shop, George Westinghouse looked up to find a young woman standing before him with a sample of the magazine *The Living Age* in her hand. She was selling subscriptions, and, although Westinghouse was not much given to reading magazines, he bought a three months' subscription for $2. Whether he had merely been persuaded by the young lady's manner, or whether, in glancing through the sample issue, his eye had caught the article that suggested an answer to his question, this purchase was destined to be one of the most important he ever made.

The article was entitled "In the Mont Cenis Tunnel" and described a unique solution to a knotty problem encountered in the construction of an unusually long tunnel being bored through the solid rock heart of the Alps. The question had arisen as to how the workmen could bore holes in the rock for blasting. An Englishman had invented a drill driven by steam, but steam requires fire, and fire requires oxygen; and at the depths they were working, the workmen needed every bit of available oxygen. Three Italian engineers had conceived the idea of operating the drill by compressed air instead of by steam,

and their apparatus was now being used in constructing the tunnel. Fresh air was compressed at the mouth of the tunnel and piped more than 3,000 feet to where the workmen were drilling. There it provided both oxygen for the workmen and power—plenty of power—to drill holes in the rock. If air could do such a mighty job for the tunnel builders, it could certainly be used to stop trains.

Convinced that at last he had found the solution, Westinghouse drew up plans for his first air-brake system. He worked out every essential detail—an air-compressing apparatus operated by steam from the locomotive boiler, a valve by which the engineer could conveniently admit compressed air into the braking system to stop the train, or release air from the system, thereby releasing the brakes. He even designed the couplings of the air pipes between cars, with valves that automatically opened when the pipes were joined and automatically closed when they were pulled apart. His plans were thorough and complete, but he now faced the problem of getting financial aid so that he could make the apparatus necessary for a practical demonstration.

He could not count on any assistance from his father, who thought young George was meddling in affairs about which he knew nothing. His car replacer business, on the strength of which Westinghouse had married before he was twenty-one, was beginning to fall off; and the situation took a sharp turn for the worse when on a gloomy afternoon in 1868 his partners informed Westinghouse that they now intended to conduct the business without his services. To young Westinghouse it was incredible and infuriating that he, the inventor of the car replacer, should be so ungraciously pushed out of his own business. But he still had one hope.

For several weeks, he had been corresponding with a steel mill in Pittsburgh which seemed to have facilities for manufacturing his car replacer less expensively than the mills nearer home. Perhaps they would be willing to manufacture his invention and let him travel among railroad men to sell it. In that case he might have an opportunity to interest people in his air brake, too.

With this plan in mind, Westinghouse set out for Pittsburgh. Not knowing the city, he left his luggage at the station and began to look for Second Avenue and Try Street, where the offices of Anderson and Cook were located. A short distance from the station he inquired his way of a tall, well-dressed young man, and as they talked, the two young men struck up a friendship that was to last a lifetime. Ralph Baggaley, before two years were out, was to become a member of the board of directors of Westinghouse's first great enterprise.

Guided by Baggaley, Westinghouse arrived at the steel mill where, after a short talk with the senior partner, it was agreed that Anderson and Cook would manufacture the car replacer at their own expense and Westinghouse would immediately become a traveling representative of the company.

Westinghouse's travels for Anderson and Cook brought him in contact with many railroad men. Whenever he had an opportunity, he tried to interest them in his air brake, but it was slow and difficult work. The idea of using air as the power to apply brakes was too original. Some felt that it showed no more promise of success than the braking system then in use. Others dismissed it as an utterly impractical, harebrained notion.

From time to time, Westinghouse reported to Pittsburgh, and on one of these occasions he met Ralph

Baggaley again and told him about the air brake. Baggaley was then general manager of a foundry and was interested in subjects of a technical nature. He listened closely and finally was so fired with Westinghouse's own enthusiasm that he offered to shoulder the expense of preparing an experimental model.

The two young men lost little time getting to work. They built the apparatus with elaborate care, and, now that Westinghouse's plans were translated into a visible, workable mechanism, the railroad men showed greater interest. But nobody seemed willing to risk a trial run with it. Robert Pitcairn, the local superintendent of the Pennsylvania Railroad, was one of the more sympathetic listeners, and he brought Superintendent Williams and Andrew J. Cassatt, also of the Pennsylvania Railroad, to examine the apparatus. They liked it and frankly told the inventor so, but they did not feel they could recommend that their company bear the cost of a practical demonstration.

The hopes of the young men, dashed by this, were soon buoyed again when Superintendent W. W. Card of the Panhandle Railroad paid a visit to their shop. He had heard of their apparatus, and after giving it a thorough going-over was convinced of its merit. He promised to see what he could do to persuade the directors of his company to defray the cost of a demonstration.

Card kept his word, and he soon returned with his company's answer: they would lend the young men a passenger train, but the cost of installing the apparatus and the additional cost of repairing damage done to the locomotive and cars in installing it would have to be paid by the inventor. This seemed to be about as far as they would ever get and, tired of waiting, the young men agreed.

The trial run was set for April, 1869. Officials of the Panhandle Railroad, including Superintendent Card, settled themselves in the rear car of the train while George Westinghouse gave last-minute instruction to Daniel Tate, the engineer.

"All I ask of you, Dan, is to give this thing a fair show," and the young inventor grasped Tate's hand to press it warmly. "Good luck to you."

When Tate reached for the bell rope, a fifty-dollar bill fell from his hand. He did not know it, but that bill represented the last dollar George Westinghouse had to his name.

The test run was between Pittsburgh and Steubenville, Ohio. Beginning at the Panhandle Station, the train had to go through town a short distance and cross the bridge over the Monongahela River before it reached open country. Precautions had been taken to prevent people from crossing the tracks; so Dan Tate, with a light heart and a warm feeling toward the inventor whose apparatus he was demonstrating, opened the throttle.

In the observation coach, the guests chatted quietly as the train passed through Grant Hill tunnel and emerged at the other side of town. Tate had pushed the train to about 30 miles an hour. Westinghouse looked out at the town with excitement and satisfaction. It had been a difficult struggle, but now at last a bright new future was opening up for him. He turned to answer a question, and suddenly all confidence was knocked out of him with a terrific jolt!

The jolt threw the distinguished guests from their seats amid a loud uproar of brakes grinding against the wheels and the frightened cries of the passengers as the train bumped to an abrupt halt. Westinghouse did not

notice the dark looks of the passengers. Rushing to the door, he jumped from the coach and ran toward the locomotive. Tate had climbed out of the engine cab. Westinghouse ran to him, and as he approached, his dismay gave way to a great wave of relief. For there on the road ahead, not four feet from the cowcatcher, was the cause of all the excitement—a drayman, thrown from his cart to the railroad tracks by his frightened horse and saved in the nick of time by the first practical application of the air brake.

The guests drew up, rubbing their bruised shins and elbows, and one by one their angry moods were changed to wonder and admiration as they witnessed how narrowly tragedy had been avoided. Their bruises were forgotten when they climbed back into the coach, and so was the lucky drayman. The thrilling demonstration had proved that the air brake was everything its inventor claimed, but if there had been any lingering doubt, it was dispelled during the remainder of the journey as Tate treated the passengers to various tests along the road—none quite so drastic as the first!

On the strength of his success, Westinghouse soon resigned his position with Anderson and Cook to devote full time to the air brake. Baggaley's firm had been dissolved, and the foundry that he had managed was turned into a temporary plant for manufacturing air brakes. An exhibition train was fitted out and sent to large eastern and midwestern cities. Orders began to come in. On April 13, 1869, Westinghouse obtained his patent for the air brake—just one month before the history-making golden spike united the tracks of the first transcontinental railroad at Promontory Point in Utah. And in July, 1869, when Westinghouse was still twenty-two years old, the

Westinghouse Air Brake Company was organized with Robert Pitcairn, W. W. Card, Andrew J. Cassatt, Edward H. Williams, G. D. Whitcomb, and Ralph Baggaley as the Board of Directors and young George Westinghouse as president.

Westinghouse's air-brake patent was the first of more than a hundred patents he received as he developed and perfected his system of stopping trains. Tirelessly, his inventive mind sought out new problems with which to grapple. In the next three years he made radical changes in his first design and received a patent for a new automatic air-brake system. This system provided for applying the brakes by reducing air pressure rather than increasing it, so that, should a brake pipe be ruptured or cars parted, the brakes would automatically be forced against the wheels. He developed the famous triple valve, which is still the basic valve for the threefold purpose of applying brakes, releasing them, and filling an air reservoir with compressed air.

His fertile imagination was brought to bear on every detail. He devised a new steam-driven pump for compressing air, which, with certain improvements, is still in use today. He brought out inventions to perfect the engineer's control of air pressure. Dissatisfied with the beam that supported braking mechanisms, he invented a new one. He worked out new and better ways of connecting the air pipes between the cars. He even developed a system, now familiar to everyone, for applying the compressed air required for braking to a signaling system for communication from car to car.

His air-brake invention rapidly grew more perfect and popular. In five years from the time he received his first patent, almost 10,000 air brakes had been installed in

locomotives and cars. Ten years after his invention of the automatic brake more than 36,000 locomotives and cars were equipped with Westinghouse brakes, 16,000 of them of the "straight-air brake" type, as the first brake came to be called to distinguish it from the automatic brake.

In 1886 and 1887 came the last great challenge to the air brake. Freight trains were growing longer and heavier, and their cars had to be swiftly and conveniently transferred from one railroad line to another. It became increasingly evident that to save time and life a uniform power-brake system had to be adopted for all freights, so that the trains could be controlled and each freight car might be attached to any other freight car in such a way that their braking apparatus would fit and work together.

The Master Car Builders' Association undertook to study existing braking systems in order to recommend the best as standard for all freights. To do this, they invited brake manufacturers to fit out a fifty-car freight train with their mechanism and to compete in trials held at Burlington, Iowa, in 1886 on the tracks of the Chicago, Burlington and Quincy Railroad.

A fifty-car freight train was an unusually long one in 1886, and, as they expected, the Master Car Builders' Association found no brake wholly adequate. The Westinghouse automatic brake proved satisfactory for normal stops, but in emergency stops the first cars came to an abrupt halt and the cars behind banged into them one after another. The system simply was not fast enough to reach the entire length of fifty cars and apply brakes in all of them simultaneously.

The following year another contest was held, and in this contest Westinghouse competed against a new form of braking mechanism operated solely by electricity. He

had improved his own system and had included a few simple electrical devices to set the brakes in different sections of the train simultaneously. But he included these with reservations, for he was not convinced that the electrical art was far enough advanced to be applied to freights. "A freight car has no father or mother," he said. It had to roam the continent and stand neglected in freight yards and sidings. Its electrical equipment could easily fall out of repair and prove inoperative when it was needed most.

Westinghouse's conviction about the unreliability of an all-electric system for braking was borne out dramatically in the 1887 trials. The train that used electrical equipment throughout to apply the brakes performed brilliantly during most of the trial, but on its last run one of the wires broke, and the braking system failed completely. The train had to coast to a stop.

The verdict of the Master Car Builders' Association was in favor of a brake operated by air but actuated by electricity, but Westinghouse still believed that a brake operated by air alone was the most reliable, and this verdict inspired one of his most brilliant and swiftest victories.

At the conclusion of the 1887 trials, Westinghouse was probably the only man alive who did not believe that his braking system was doomed. Making arrangements with the Chicago, Burlington and Quincy Railroad, he obtained permission to use tracks and locomotives for continued trials. His inventive mind was busy again. He redesigned the valves and pipes and reservoirs, and soon carloads of new braking equipment were being shipped from Pittsburgh to Burlington. The fifty-car freight was fitted and refitted from one end to the other three times before Westinghouse was satisfied. But when he was

finished, three months after the conclusion of the official trials, he had completely remodeled his system and had made his air brake so effective that without the aid of electricity the brake was applied to the very last car in the train almost the instant the engineer moved the valve. This train was sent to many major railroad centers, where the tests were repeated before railroad men, and in 1888 the Master Car Builders' Association recommended it as the standard brake for freight trains.

During the years in which Westinghouse was perfecting his air brake, he was busy with many other things. In addition to administering a rapidly growing business, he spent much of his time in England and on the Continent, bringing his inventions to the attention of railroad people there; and one by one Westinghouse shops and companies began to dot the map of Europe.

It was in England that he got the idea for his friction draft gear, called by some railroad engineers his greatest contribution to railroading. This was a device to take the place of heavy springs in the couplings between cars. Often, as trains stopped, the springs between cars were pressed together, the length of the train becoming as much as 15 or 16 feet shorter. The energy stored in the springs was released when the brakes were released. Snapping out, they would push the cars apart, sometimes with such force that couplings would break and the train would be parted. The friction draft gear was based on an entirely different principle. The energy of cars crowding up on one another as the train drew to a stop was spent in overcoming friction in the coupling, rather than in storing it in a spring. This meant that there was no reaction when the brakes were released, and it also enabled a train to get up to a speed of 20 miles an hour before a similar train equipped

with springs could be entirely put in motion! The friction draft gear made possible enormous saving by eliminating injuries, loss of time, and damage to merchandise.

It was in England, too, that Westinghouse first became interested in railroad signaling. In 1881, when he had returned to the United States, he organized the Union Switch and Signal Company and began to apply his inventive genius to the difficult and complex art of traffic control. In the early days, switches and signals were moved by hand, but Westinghouse foresaw that with the vast increase of traffic and the development of railway yards, where trains had to be directed quickly and safely, this crude method would have to give way to the use of power. Combining the forces of electricity and compressed air, he devised a system for automatically controlling signals and for interlocking complex signals so that they could not possibly direct trains into danger. His inventions went far to revolutionize the art of railroad traffic control, and his interest and leadership in this work continued throughout his life. His very last invention, for which a patent was issued more than four years after his death, was for a method of slowing or stopping trains automatically without any action on the part of the engineer.

But Westinghouse's activities did not end with railroading, for in the early 1880's he had begun to manufacture power for a new age of industrialism, and by 1886 he had made the first step toward revolutionizing the art of manufacturing the greatest of all power sources—electricity.

Today we take power for granted. A flip of a switch turns on a lamp or a vacuum cleaner or sets a giant machine in operation. We seldom think twice of the source, because we have learned to rely on electricity as a swift, clean, always obedient servant. In the early 1880's, how-

ever, electricity was just beginning to show promise as a power source. Its usefulness for telegraphy and telephones was known, but the first installations of direct-current systems were almost solely for lighting, and the fact that direct current could not economically be carried over long distances threw some doubt on its value as an all-around source of power.

For industrial purposes, the main power source was the steam engine. Belts and pulleys were used to transmit the power from one steam engine to several machines, but at best the system was cumbersome and inefficient. Sometimes a steam engine was used to compress air, and the air was piped to the place where it was needed, as in Westinghouse's own air-brake system. But efficient machinery had not been made for utilizing air pressure, and besides, there were narrow limits beyond which it was too expensive to transmit air except for special requirements.

Yet the cry of the times was for more power—power to reach and build new industries, power to produce more goods, power to translate the flowing ideas of an inventive nation into useful merchandise. There was plainly a need for some way to transmit this vital ingredient swiftly and economically from its source to the machines or devices that consumed it, but there was no convincing answer to this need in sight.

Westinghouse had always been interested in power and transmission of power. His first invention had been for a rotary steam engine, but even before that, as a boy, he had shown ingenuity in his father's shop by tying several machines together with belt drives to a single steam engine. In the development of the air brake his chief problem—how to transmit power from a central source to several remote mechanisms—remained unsolved until he

hit upon the use of compressed air. His success after the Burlington trials in finding an efficient brake for freight trains was another step in transmitting the power of compressed air more swiftly over a longer distance. His career was, in fact, a succession of triumphs in the mastery of power and its application to useful purposes.

It was almost inevitable that the possibilities of electricity should capture his imagination. He had toyed with the idea of using electricity in his braking and signaling systems. In 1880 he had invented an automatic telephone exchange. He started a small "electric lighting department" in the Union Switch and Signal Plant at Garrison Alley in Pittsburgh, and in 1884 brought to it the brilliant young electrical engineer, William Stanley, later famous in the annals of electricity. On the basis of Stanley's inventions for an incandescent lamp and for a self-regulating generator and of experiments performed in the electrical laboratory, he started building direct-current equipment to be installed in hotels and cities.

But Westinghouse, like many others, was not entirely convinced that electricity was the best source of power. He had yet to discover the possibilities of alternating current, and before he did, he had already completed his first great experiment in the development and transmission of an entirely different sort of power. He had organized the Philadelphia Company to provide homes and industries in Pittsburgh with natural gas.

Westinghouse's venture with natural gas began in his own back yard, when late in 1883 he issued a contract for a well to be bored on the grounds of his Pittsburgh home, "Solitude." It was known that natural gas was abundant in and around Pittsburgh, but only one or two companies had made any attempt to control and utilize it. Besides,

natural gas was dangerous. It had no odor and could not easily be detected. Passing under tremendous pressure through pipes from the gas wells to homes or industries, it leaked out of every crevice or imperfection and occasionally caused violent explosions.

Despite its hazards, however, one industrial plant had made a study of the use of natural gas, which proved that it was as useful for their purposes as any other kind of fuel and much less expensive. This study attracted Westinghouse's attention, and soon his mind was busy speculating on the possibility of controlling such valuable fuel. He had controlled compressed air; perhaps he could harness this force, too.

Late in February, the drillers at "Solitude" tapped a small vein of gas, and Westinghouse urged them on. The excitement of the new venture gripped him. He spent his evenings devising new drilling tools or improved methods of prospecting for gas. Frequently he donned his overalls and crossed the lawn to beyond the stables where the men were boring. Deeper and deeper they went into the earth until the well was sunk almost a third of a mile. And then they found gas—enough gas to challenge the ingenuity even of Westinghouse.

It was three o'clock in the morning when Westinghouse was startled from sleep by a thunderous crash and a terrifying roar. This was it! But a few minutes later, as he rushed, hastily dressed, from the house, he saw that it was more than he had bargained for. Jetting from the deep well was a vast geyser of filth—mud, gravel, sand, water. The huge derrick looked battered. The drilling machinery was nowhere to be seen. The lawn and paths were littered with debris, and the spewing hole hissed and roared with the infernal violence of a volcano.

While the dawn was still gray, people from a mile around came to witness the terrifying sight, and Westinghouse and the workmen were devising means for bringing order out of the devastation. As the day wore on, they discovered the drilling engine tossed some distance away and entirely buried under debris. The geyser of filth was beginning to subside, and a stream of pure gas issued with hurricane velocity from the well. Experimentally, one of the workmen tossed a heavy piece of coal over the opening. The gas hurled it into the air and smashed it against the beam of the derrick. Another workman attached a hundred pound rock to the end of a rope and swung it over the mouth of the well with the derrick. The rushing gas shook and tugged at the stone until it was free and then threw the loose end of the rope straight up in the air and held it there, stiff as a pole.

There was little peace in the neighborhood of "Solitude" for the next week, until Westinghouse, with his usual dispatch and ingenuity, devised a stopcock and brought the roaring jet under control. But the fun was not over. Constructing a 60-foot pipe at the mouth of the well, Westinghouse treated his neighbors to further frightening displays by shooting a fountain of fire 100 feet into the night sky. A few evenings of this convinced him of the valuable quality of his gas, and then he was ready for business.

By the beginning of the summer, he obtained his first major patent for a "System for Conveying and Utilizing Gas Under Pressure." By the end of the summer he organized the Philadelphia Company. One after another, Westinghouse's inventions poured forth—twenty-eight of them in 1884 and 1885 alone. They touched and transformed every aspect of the system. He devised better

methods of digging gas wells, a meter for measuring the amount of gas used, methods of preventing and detecting leaks, a regulator for controlling the amount of air combining with gas in a steam furnace. One group of ingenious inventions eliminated a serious danger in the use of natural gas. Often the supply of gas was shut off or the pressure fell to a point where the gas flame went out. When the pressure was renewed, gas would escape from the jets unconsumed and unnoticed. A spark could set off a devastating explosion. Westinghouse devised an automatic control which shut off the main supply of gas whenever the pressure fell below the point at which gas flames would die. No gas could flow through the jets when the pressure returned, until all the cocks in the building were closed. Then the supply could be renewed by pressing a button on the regulator.

Westinghouse continued as president of the Philadelphia Company until 1899. The inexpensive fuel which this company provided drew many industries to Pittsburgh, including large iron and steel concerns, and these helped develop that city into one of the great industrial centers of the world. To make the use of gas even more universally applicable, Westinghouse invented and manufactured gas engines which for a while competed with steam engines and grew in importance until both the steam engine and the gas engine were superseded by the steam turbine. He even organized the Fuel Gas and Electric Engineering Company in 1887 to devise means for manufacturing gas in case the supply of natural gas should run out.

One of his most noteworthy contributions to the art of handling gas was his invention of a system for conveying gas over long distances. The pressure of gas at th

well is much greater than the pressure required by the consumer. Westinghouse utilized this very high pressure to drive the gas speedily through a comparatively narrow pipe for four or five miles. Then, by widening the pipe at intervals, he reduced the pressure until it was just strong enough for use when it reached the consumer. It was this same basic idea for distribution—high pressure at the source and reduced pressure at the point of use—that lay behind Westinghouse's plan for supplying electric power over long distances.

By 1885, Westinghouse had discovered to his own satisfaction that the chief obstacle to the use of direct-current electricity as a universal power source was that its pressure, or voltage, could not be controlled without loss. To transmit electrical energy over great distances, the voltage must be high, much too high for the working voltages required at the point of use. Since the voltage of direct current cannot economically be raised or reduced over wide ranges, the voltage produced by the generator must be approximately the same low voltage as that used by the lamps or machinery it supplies. Consequently, direct-current generators could provide electricity commercially at distances no greater than a mile. To supply a city would require many generators, and the cost would be prohibitive. To supply outlying communities was out of the question.

The nucleus of young men in the electrical department of the Union Switch and Signal Company had grown, and Westinghouse was still building electrical equipment. But it was not until 1885 that his interest was fully aroused and that he began to bring to the field of electricity the same great vision and leadership with

which he had revolutionized the art of railway transportation and the art of handling natural gas.

Guido Pantaleoni, who held a responsible position with the Union Switch and Signal Company, was visiting his native Italy, and there, through his former electrical professor, Galileo Ferraris, he met a Frenchman by the name of Lucien Gaulard. Gaulard, with John Dixon Gibbs, an English engineer, had invented a system of distributing alternating current, and one of the devices they used was a "secondary generator," which could step the alternating-current voltage up or down. Pantaleoni conveyed this information to Westinghouse, who was quick to grasp the far-reaching importance of the device. He obtained an option on the system, and by autumn of that year several Gaulard-Gibbs secondary generators, or "transformers," as they later came to be called, were at the electrical department of the Union Switch and Signal Company—along with another brilliant young engineer, Reginald Belfield, who had been closely associated with Gaulard and Gibbs. Belfield and William Stanley undertook to redesign the transformer electrically. Westinghouse and Albert Schmid, a young Swiss engineer, set about redesigning it mechanically. The results were so promising that on January 8, 1886, even before any practical demonstration was performed, Westinghouse organized the Westinghouse Electric Company to manufacture and promote the use of alternating-current system equipment.

The practical demonstration came soon afterward. The Gaulard-Gibbs transformer was rapidly changed and revised until a solidly designed, electrically sound commercial transformer emerged. Rights to the Gaulard and Gibbs patents were acquired in February of 1886, and th

next month a small New England town witnessed the first demonstration in this country of the alternating-current system.

Because of ill-health, William Stanley had moved to Great Barrington, Massachusetts. There, with Reginald Belfield, he set up experimental equipment in an abandoned rubber mill about ¾ mile from town and worked steadily to perfect the system. They erected a 25-horsepower steam engine in the old mill and belted it to an alternating-current generator, which had been sent from England along with the transformers. They connected transformers to the generator and led wires down the main street of the village, fastening them to the elm trees that bordered the sidewalks. "I have . . . placed a converter (transformer) in my cousin's store in order to test the commercial necessities," Stanley wrote to Westinghouse on March 17, 1886. "The lamps in the store were running well last night . . . I am striving all I can to finish this system for you at the earliest possible date . . . I might say a great deal about the system but briefly, it is all right."

And it was all right! Stanley and Belfield connected a half dozen transformers in the cellars of buildings to be lighted. Then on March 20, 1886, Stanley closed the switch. Lights glowed in the town of Great Barrington, and George Westinghouse, who at thirty-nine years of age had already established a world-wide reputation and had built world-wide businesses, was launched on another career—his most turbulent and triumphant.

The Union Switch and Signal Company moved to Swissvale, a suburb of Pittsburgh, and the Garrison Alley plant became the first home of the Westinghouse Electric Company. Here alternating-current equipment was built,

including a new constant-voltage alternating-current generator, which Stanley had designed. The first commercial system was built by autumn of 1886. Under test it kept 400 lamps lit for a fortnight in Lawrenceville, four miles away—the first successful demonstration of transmission of electricity over any considerable distance. Then the same equipment was shipped to Buffalo, New York, and put into service in November, the day before Thanksgiving. The alternating-current system had been proved a success, and the young company started out its new year with orders for twenty-seven additional installations.

But there were immense problems still to be solved. First and foremost was the need for certain critical alternating-current equipment. It was one thing to send electricity over great distances, but it was quite another to utilize it as a power source and to measure its consumption. Before alternating current could fulfill its great promise, at least two devices had still to come: an alternating-current meter and an alternating-current motor. They came within a month of each other, and they brought another revolution in electricity.

On an April day in 1888, Oliver B. Shallenberger, another of the coterie of young engineers at the Westinghouse Electric Company, was testing an alternating-current arc lamp in a laboratory at the Garrison Alley plant. A small spring happened to drop on the spool of a magnet coil near a projecting core of laminated iron. Shallenberger knew that Westinghouse had been casting about for an alternating-current meter, and now, as he reached to pick up the spring, he realized that he had accidentally hit upon the principle that would make one possible, for, caught in the shifting magnetic field, the spring was slowly

rotating. Out of that he knew he could make a meter, and in exactly one month he did.

From this discovery, Shallenberger could easily have satisfied the second great need, for an alternating-current motor; but even while he was working on the meter, the principle of the alternating-current motor was revealed by two men almost simultaneously. One was Galileo Ferraris, of Turin, Italy, the professor who had introduced Guido Pantaleoni to the inventor of the transformer. The other was Nikola Tesla, whose epoch-making patents for a polyphase system of alternating current were awarded on May 1, 1888.

Westinghouse was prompt to see the importance of Tesla's disclosures, and on July 7 he obtained exclusive rights to them. At the same time, he persuaded the brilliant young inventor to join the Electric Company and help perfect the motor. When Tesla arrived in Pittsburgh, he brought with him a working model of his alternating-current motor, but it was not until four years later, in 1892, that the motor was finally perfected and ready for commercial use.

There were two main reasons for this long and costly development. One was that the motor required a polyphase system. Until that time, alternating-current systems were single-phase, the current moving forward during one half cycle, and backward during the second half cycle. Tesla's alternating-current, or induction, motor required two or more such currents whose cycles of alternations were not simultaneous. The completely new system of polyphase generation and transmission had to be developed.

The second reason was that the frequency of the alternating-current equipment then being built had to be changed. The single-phase system used a frequency of

133 cycles a second: current changed its direction back and forth 133 times a second. This was too rapid for the polyphase motor, and, after much deliberation, a 60-cycle system for general use was decided upon and has since remained a standard alternating-current frequency.

When these obstacles were overcome, the induction motor, rebuilt and revised from the ground up, was offered for sale. Industries began installing the polyphase system, and the great shift from the use of steam power to the use of electricity to drive machines began.

The greatest threat of all to the development of the alternating-current system, however, lay, not in the early lack of alternating-current equipment, but in the violent opposition to the whole idea of using alternating current. This opposition, by the proponents of a direct-current system, began as soon as it became evident that Westinghouse seriously intended to develop alternating current on a large scale, and it continued bitterly for many turbulent years in what came to be known as the "battle of the currents."

When electricity first came into use, current was carried in overhead wires—an obvious hazard, but one which attracted little attention until Westinghouse proposed his high-voltage alternating-current system of distribution for New York City. Immediately a great hue and cry went up. Every accident was seized upon by newspapers to create in the people's mind a fear of the dangerous and deadly "Westinghouse current." One Martyr More, the headlines read; Another Lineman Roasted to Death, The Electric Murderer, Again a Corpse in the Wires. Every incident was described in macabre detail, and some newspapers even set up special departments for describing injuries or tragedies resulting from electrical hazards.

When Westinghouse suggested underground cables, one technical writer, dismayed by the whole idea, wrote: "The choice is . . . not between the present electric lighting and the same with underground cables, but between the present system and a return to gas . . . The attempt to place all wires under ground would result in such an original and continued upturning of streets as would render them impassable, and might cause more injury and loss of life from malaria in a month than the electric wires have occasioned in seven years." Thomas Edison, a leading antagonist of the alternating-current system, believed that no insulation was adequate to control Westinghouse's high voltages and that alternating current in underground cables would burn out its containers and enter houses through manholes!

One electrical man, Harold P. Brown, gave a talk at the Columbia School of Mines, during which he tortured and killed a great black dog with alternating current. He was about to bring home his point with a second victim when the superintendent of the Society for the Prevention of Cruelty to Animals stopped him. The same Mr. Brown installed the first electric chair for executing criminals in New York State—using Westinghouse equipment which he had acquired through a middleman. The first use of the electric chair was, of course, a great subject of discussion, and the success of alternating current on this widely heralded occasion only helped to establish it as a man-killer.

Through most of this, Westinghouse patiently awaited an opportunity to persuade the public that he was right and his opponents wrong. In the meantime, he wrote one article for the *North American Review* in 1889, "A Reply to Mr. Edison," in which he matter-of-factly refuted

statements made in a previous article written by Edison for the same magazine. But he moved steadily and courageously against his opposition, sure of the worth of the alternating-current system. Whether any other man could have so successfully resisted such violent opposition is open to question; Nikola Tesla, many years after the battle had been won, thought that Westinghouse was the "only man on this globe" who could have done it.

Westinghouse's chance to break through public prejudice against the alternating-current system came in the spring of 1892. The directors of the Columbian Exposition, a gala World's Fair to be held in Chicago the following year, had asked for bids from manufacturers for a contract to light the fair grounds. The most likely candidate for the contract seemed to be the General Electric Company, which had recently taken over the Edison interests and was now the great stronghold for the direct-current system, for that company held the patent on the only really practicable glass bulb for incandescent lamps. They offered to illuminate the fair at a cost of between $13.98 and $18.51 a lamp. But Westinghouse meant to put his alternating-current system to a large-scale test, and when the bids were opened on May 23, 1892, the contract was awarded to him for the phenomenally low figure of $5.25 a lamp!

To many of his associates, this seemed like a reckless plunge. Although Westinghouse admittedly could build all the equipment to light the lamps, to buy bulbs from the General Electric Company would have swamped him financially, and to build a competitive bulb in the face of all the adverse patents then in existence seemed well-nigh impossible in so short a time. But the reward would be great. Success at the World's Fair would provide tangible,

visible refutation of all the ill-repute that had surrounded the alternating-current system during the "battle of the currents." This was the sort of challenge George Westinghouse knew how to meet.

Westinghouse owned the rights to a patent for a two-piece bulb invented in 1880, and with this as a starting point he set to work. He transformed this bulb into the famous two-piece "stopper lamp," with a ground-glass stopper that fitted into the base of a glass globe like a cork. He invented a more efficient vacuum pump and developed a new technique for removing the last traces of air from the bulb. He set up a glass factory in Allegheny. New machines for grinding the globe and the glass stopper were designed almost overnight. And while all this was going on, he was defending himself from a subtle legal campaign designed to prevent him from building his lamps and meeting his contract with the fair. Few people, indeed, believed that Westinghouse could win this battle against his powerful business adversaries and against his even more formidable adversary, time. But when the Columbian Exposition opened on May 1, 1893, the Westinghouse lighting plant was one of the very few large exhibits that was complete and ready for operation.

In less than a year, Westinghouse had built 250,000 stopper lamps to light the fair and to provide ample replacements. Twelve 75-ton polyphase generators, the largest of their kind built in this country up to that time, provided 12,000 horsepower of electrical energy to keep the lamps lit and to run the Westinghouse exhibit. The exhibit itself, apart from the spectacular lighting, displayed a complete polyphase system in operation. A 500-horsepower induction motor, driven from the main generators, turned the polyphase generator for the ex-

hibit. To this generator was attached a transformer, which stepped up the voltage. Then came a short transmission line with transformers for lowering the voltage again. The current was used to run induction motors, a synchronous motor, and a new development called a "rotary converter," which changed alternating current to direct current for operating a railway motor. A huge marble panel, 1,000 square feet, contained all the switchgear to operate both the lighting system and the exhibit, and one man, connected by telephone and messenger with every part of the fair grounds, could meet any possible emergency simply by throwing a switch.

The lighting and display were proof to the public that the "Westinghouse current" was not the demon they had been led to believe it, but a versatile power, easily and cleanly transmitted and universally useful. The Columbian Exposition spelled the beginning of the end of the "battle of the currents."

The fair lasted six months, and during that time the Cataract Construction Company, which for several years had been studying ways of harnessing and utilizing the tremendous wealth of natural power at Niagara Falls, arrived at two decisions that established once and for all the superiority of alternating current over every other means of transmitting power. In May, 1893, during the first month of the Columbian Exposition, the Construction Company put itself on record as favoring alternating current, and in October of the same year the company awarded Westinghouse a contract to build three huge generators for changing the energy of the falling waters of Niagara into electrical energy.

The Cataract Construction Company had been formed in the late eighties to finance and execute plans for harness-

ing the potential power of Niagara's rushing waters. The original plans, devised by an Erie Canal engineer in 1886, called for a tunnel 1½ miles long underneath the town of Niagara Falls, parallel to the river. Water would be taken from the upper end of the river and diverted into 238 shafts 150 feet deep. At the bottom of the shafts were to be placed turbine wheels, which would be driven by the falling water. These wheels would provide power for factories built above them, and the water would be tunneled back to the river below the falls.

With this concept in mind, the Cataract Construction Company bought property near the falls, but, before embarking on the project, they decided to give careful consideration to the best way of harnessing water power. In 1889, Edward D. Adams, the president of the company, and Dr. Coleman Sellers, its chief engineer, visited Europe to observe how water power had been brought under control there. In Geneva they saw water power distributed under pressure through pipes; but the power could not be delivered more than a mile. In Berlin they saw a 1,000-horsepower direct-current generator operated by water power; but the power was transmitted only half a mile. The further they traveled, the more they realized the need for sound advice, and in June, 1890, they organized the International Niagara Commission, composed of five men of great eminence, headed by Sir William Thompson, who later became Lord Kelvin.

The commission's first task was to report on the relative merits of transmitting power by compressed air, by water, by electricity, or by mechanical means, such as belts, cables, and gears. The decision was in favor of electricity, but there was still the question of what kind of electricity—direct current or alternating current. While

the commission was making these studies, Westinghouse was making great strides in developing his system. The alternating-current motor was being perfected. The rotary converter for changing alternating current to direct current was being developed. And in 1892 all efforts were speeded up to meet the contract for illuminating the Columbian Exposition.

Late in 1892 Westinghouse completed two 150-horsepower rotary converters. He invited the Cataract Construction Company to inspect them, and early in 1893 Dr. Sellers and two of his colleagues tested them with satisfactory results. The rotary converter was of great importance in the alternating-current system, because while alternating current was certainly the best for long-distance transmission, direct current had to be available for certain uses—for example, in railway motors and in electroplating. The rotary converter made it possible to transmit alternating current from a large central power station and to change it to direct current at places where direct current was required. This eliminated the last remaining excuse for the transmission of direct current.

The commission's final report was in favor of an alternating-current transmission system, and in May, while the complete polyphase system was on display at the Columbian Exposition, the Board of Directors of the Cataract Construction Company approved the adoption of alternating-current generators.

Westinghouse had already built two hydroelectric plants, one at Oregon City, Oregon, which supplied power to Portland, Oregon, 14 miles away, and one at Telluride, Colorado, which supplied power to Gold King Mine, three miles away. But both of these plants were small, and, although they had only recently been completed, they

were already old-fashioned, for they were equipped with single-phase generators with only 100 horsepower.

The proposal for Niagara Falls called for three 5,000-horsepower polyphase generators, and once again the equipment had to be engineered from the ground up. But in 18 months the first water-driven generator was completed. It was installed on April 21, 1895. In November, 1895, all three generators were ready for operation, and a year later, three seconds after midnight on November 16, 1896, engineers at Buffalo closed the circuits that brought power from the mighty Niagara, 20 miles away.

The effect of the Niagara Falls development was far-reaching. Before long, generators at the falls were providing electric power for large sections of western New York State. Attracted by the available power, new industries sprang up there. Electrochemical companies gathered until the Niagara Frontier became the largest electrochemical center in the world. Electricity made the commercial production of aluminum possible, and for many years all the aluminum produced in America came from Niagara Falls. It also facilitated the production of carborundum and a wide variety of other metallurgical products. Inexpensive, versatile power had given rise to a new and growing industrial region.

But more important was the fact that Niagara Falls showed by its giant example the inestimable value of alternating-current transmission systems. Soundly and thoroughly thought out, it set the pace for vast developments in the manufacture of electrical power all over the world and fulfilled the vision that for ten years George Westinghouse had cherished and struggled to achieve.

With the installation of alternating-current generators at Niagara Falls, Westinghouse concluded one period

of prodigious effort and began another, during which he added two crowning touches to the modern industrial age with the introduction of the steam turbine and the alternating-current railway locomotive. In the fifteen years from 1881 to 1895, he had received 150 patents. Seventy-one of them were granted during the critical years of 1885, 1886, 1887, and 1888, when he was building the Philadelphia Company, organizing the Electric Company, contributing to the early growth of the Union Switch and Signal Company, and developing the quick-action air brake for the Burlington trials. Despite the rapid expansion of his organizations, he had weathered the depression of 1893 by a brilliant stroke of financing. He had fought powerful interests to introduce his alternating-current system. He had performed the seemingly impossible feat of illuminating the Columbian Exposition. Under his leadership the Westinghouse Electric Company, the forerunner of the present Westinghouse Electric Corporation, had grown into a mighty industry and had moved from its quarters in Garrison Alley to the colossal new plant at East Pittsburgh.

At about this time, Westinghouse's interest was caught by reports of successful trials of the *Turbinia*, a vessel driven by a steam turbine, which Charles A. Parsons, an English inventor, had developed. All his life, Westinghouse had worked for new and better engines. His first invention, a rotary engine, was an attempt to build a steam engine that would prove more efficient than the reciprocating, or push-pull, steam engine, but this invention was never developed commercially. His venture with natural gas led him to develop powerful and widely used gas engines for industrial applications, but he continued to search for a practicable rotary steam engine until he acquired the

exclusive rights to manufacture the Parsons steam turbine in America. This was the answer to a problem that had intrigued him since he was a boy.

Westinghouse and his engineers promptly set about revising the steam turbine to make it suitable for driving electric generators in the manufacture of electric power. They made important changes both in the turbine and in alternating-current generators, and in 1899 the first turbine-driven alternating-current generator was installed in Westinghouse's own Air Brake plant at Wilmerding, Pennsylvania. In the following year, 1900, Westinghouse installed for the Hartford Electric Company the first turbo-alternator in the country for manufacturing electric power at a central station. The turbine was just about four times as powerful as any other turbine in the world at that time.

Within a few years, the steam turbine made the reciprocating steam engine, along with Westinghouse's own gas engine, obsolete as a driving force for alternating-current generators, and Westinghouse now looked forward to the use of turbines for driving the propellers of ships. Parsons had shown that this was possible, but there were still fundamental problems to be solved before the turbine could be accepted on a large scale as the prime mover of large marine craft. The chief difficulty was that a steam turbine operates most efficiently at very high speeds, whereas a propeller operates best at very low speeds, and to gear the two together so that both might operate efficiently involved many complex mechanical problems. To solve them, Westinghouse called on the assistance of Rear Admiral George W. Melville and his associate, John H. MacAlpine. These two men made an exhaustive study of the problem, and after three years of work announced an

original and carefully worked out scheme for a gear drive. In 1909, a 6,000-horsepower gear was successfully tested at East Pittsburgh, and in 1912 the first turbine gear drive ever used on a United States vessel was put in operation by Westinghouse on the 20,000-ton Navy collier, *Neptune*. The trial run of the *Neptune* was a sweeping success, and the efficient and compact geared turbine began quickly to replace reciprocating steam engines as the driving force of seagoing vessels. It was a grand fulfillment, near the end of his life, of a development Westinghouse had envisioned almost half a century before.

The other crowning achievement in his career, already immeasurably rich in its contribution to the rise of industrial America, came in 1905 when Westinghouse introduced the first alternating-current locomotive. The company had been a leader in the manufacture of railway motors ever since it had brought out the famous single-reduction-gear motor in 1890. This motor caused radical changes in the development of electric streetcars and is still the basic type motor in direct-current railways. With the development of alternating-current apparatus, however, Westinghouse foresaw the lengthening of electrified railroad lines and the growth of interurban and main-line electric systems. Once again, the limitation of direct current became evident; for Westinghouse was convinced that wherever long-distance transmission was required, whether for lights or power or railway locomotives, alternating current was more economical and practical.

The first major application of alternating current to a railway system was in New York. Westinghouse built the huge alternating-current generators to provide current for the Manhattan Elevated and later for the New York Subway. But the motorcars used direct-current motors,

so that rotary converters had to be installed at intervals along the line to convert the alternating current from the generating plant to direct current for driving the motors. While less expensive than a straight direct-current system, this system was still costly, and it was commercially practical only in crowded areas where the traffic was heavy. Westinghouse wanted a complete alternating-current system, and in 1905 he had one.

The first single-phase railway locomotive was demonstrated on May 16, 1905, in the East Pittsburgh railway yards. The occasion was a momentous one. Westinghouse had hired a special train to bring from Washington every available railroad man attending the International Railway Congress. One practical demonstration, he knew, was the most convincing answer to all questions and arguments. The engineers had worked feverishly to complete the locomotive, and so narrow was their margin of time that they could not give it a trial test before it was exhibited to the distinguished audience. But in every detail the locomotive fulfilled the faith Westinghouse had in it. Matched against a steam locomotive of equivalent size in a series of trials, it showed its superiority in handling a train of fifty new steel cars built especially for the occasion.

This was the first electric locomotive of its size, the first alternating-current locomotive, and the first real main-line electric locomotive. Soon after the demonstration, Westinghouse undertook the task of electrifying the New York, New Haven and Hartford Railroad with the single-phase system between Woodlawn, New York, and Stamford, Connecticut. This was one of the most difficult assignments the company had yet been given, for it was of such vast scope that practically all new equipment had to be designed and built. But in June, 1907, the work was

complete and regular service began. In a sense the electrification of this span of railroad track was a consummation of Westinghouse's great career, for it combined into one masterful work of engineering his revolutionary contributions both in the development of railways and in the development of the alternating-current system.

In 1910, the aging inventor was all ready to make a fresh start. The automotive industry had begun to develop, and Westinghouse, seeing its future possibilities, made his first contribution to this field with the invention of a compressed air spring for taking the shock out of automobile riding. He started a concern for manufacturing this invention, but it was the last major concern he was to found. In 1913, the first signs of a heart ailment appeared, and his doctor ordered him to rest.

For George Westinghouse, rest was almost unheard of. He had been a tireless, unremitting worker all his life. Virtually every minute of his time was devoted to his far-flung enterprises and his far-reaching plans. He even had a special private railway car, the *Glen Eyre*, on which there were not only sleeping quarters, a dining-room, and a kitchen, but also an office where he transacted business with his traveling guests or dictated notes to his secretary while en route from place to place. But now, by doctor's orders, he confined himself to long, unoccupied hours on his estate at Lenox, Massachusetts.

Sometimes he whiled away a morning fishing from a rowboat that he kept moored at the edge of the lake. On one occasion his boat had been taken away for repairs and a substitute left in its place. Unaware that the substitute was keelless, Westinghouse stepped into it and the next moment was up to his chest in the water. Not wishing to disturb his nieces, who were playing tennis a short dis-

tance away, he took a roundabout way to the house in his wet clothes. That night, though, the old man's secret was out when he fell into violent paroxysms of coughing. For weeks he remained ill, his great body slowly wasting away. He rallied enough to regain his feet and visit his offices, but on his return to Lenox, his health was completely broken and he was confined to a wheel chair. His restless mind still could not reconcile itself to inactivity, and he whimsically worked out designs for a wheel chair which he could raise or lower or rock or wheel by electricity. But the virile power of the man was ebbing, and on the morning of March 12, 1914, while in New York trying to settle his affairs, he passed quietly away.

Thus was brought to a close one of the most spectacular and brilliant careers in the history of industrial America. For half a century—probably the most important half century in industrial history—George Westinghouse had been at the forefront of affairs. His inventive mind, his farseeing vision, his indefatigable persistence and leadership, had helped to usher in a new and fundamentally revolutionized world. No task had been too big for him, no challenge too great. His genius struck at the root of things, and his probing mind found great answers for great questions.

Honors accrued to him. Union College, where he had spent three months in his youth, conferred upon him the degree of Doctor of Philosophy. He was awarded the John Fritz medal and the Franklin Institute's Scott premium and medal. He was one of two honorary members of the American Society for the Advancement of Science. Abroad, he was made a member of France's Legion of Honor. King Humbert of Italy decorated him with the Order of the Crown. King Leopold II of Belgium decorated him with the Order of Leopold. In Germany he

was the first American to receive the Grashof medal, the highest honor bestowed by that country on an engineer. In 1912 his great leadership in developing the alternating-current system was recognized when he received the Edison medal, named for his strongest opponent.

But these honors, great as they were, could not match the dimensions of the work he had performed. The magazine, *Life*, celebrating his birthday in 1899, said, "Where Shakespeare wrought in words, you work in iron and steel." The greatest monuments in his honor were his own contributions to the entire civilized world.

In 1946, one hundred years after the birth of George Westinghouse, the great industries which he founded still flourish, among them the Westinghouse Air Brake Company, the Union Switch and Signal Company, the Canadian Westinghouse Company, the Philadelphia Company, and largest of them all—the Westinghouse Electric Corporation.

The work that he began has been continued by the men of Westinghouse on a vast scale. Today 225 billion kilowatt-hours of electric power are consumed each year in the United States alone—almost all transmitted in the form of alternating current. Westinghouse waterwheel generators, developed from the epoch-making machines installed at Niagara Falls, now harness the falling water of Grand Coulee Dam and transmit electric energy under a pressure of 287,000 volts for hundreds of miles around. Turbo-alternators, with turbines of 220,000 horsepower, provide enormous quantities of power for homes and industries, and Westinghouse scientists and engineers have helped develop the most potent energy source of all—atomic energy.

Great spans of railway have been electrified with the

single-phase system, the greatest of them being the Pennsylvania Railroad between New York and Washington. Turbines have become virtually the standard source of power for moving cargo vessels and Navy warships and are now coming to be used for driving locomotives. The newly developed gas turbine is an essential feature in certain jet-propelled airplanes.

The Westinghouse Electric Corporation has provided American homes with more than 30 million household appliances—electric washing machines, irons, vacuum cleaners, stoves, toasters, percolators. Westinghouse has helped develop the most common form of electric transportation system in the world—the electric elevator—and has installed the largest elevator system in the world at Rockefeller Center, New York.

The first regularly scheduled radio programs were produced by Westinghouse Electric in 1920, and today Westinghouse builds electronic equipment of almost every variety. The Ignitron, the modern electronic device that replaces the rotary converter as a means of changing alternating current to direct current, provides power to run streetcars and to make magnesium and aluminum. The Precipitron, an electrostatic air cleaner, rids air of particles one hundred times smaller than the eye can see. The Sterilamp, an electronic germicide, sheds rays of death on air-borne microorganisms. Thousands of miles of fluorescent lamps provide cool, bright light for homes, offices, and factories.

These are just a few of the things that have grown from the pioneering of George Westinghouse; and the engineers and scientists and workers of the great companies that he founded are carrying on with his same pioneering spirit to build for the future.

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